

60/292,108

SIGNAL PROCESSING APPARATUS AND METHODS FOR OBTAINING
SIGNAL SIGNATURES OF INVESTIGATIONAL FEATURES DETECTED
ON A SURFACE OF AN OPTICAL DISC ASSEMBLY

5 CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of United States Patent Application
Serial No. 09/331,329 filed May 14, 1999.

BACKGROUND OF THE INVENTION

1. Field of the Invention

10 The present invention relates in general to optical discs, optical disc readers, and
optical disc writers. More specifically, but without restriction to the particular
embodiments hereinafter described in accordance with the best mode of practice, this
invention relates to the use of standard optical disc drives that permit the discriminable
acquisition of a variety of different types of signals from an optical disc assembly. The
15 disc assemblies include optical bio-discs having encoded information as well as
investigational structures or features that are deposited on external or internal surfaces
of the disc.

2. Discussion of the Related Art

Commonly assigned, co-pending U.S. Patent Applications Nos. 09/183,842 and
20 09/311,329 describe methods and apparatus for detecting operational and
investigational structures on one or more surfaces of an optical disc assembly. Some of
the methods and apparatus discussed in these applications detect investigational
structures by physically modifying certain processing circuits in the optical disc drives.
As an alternative to these and similar approaches, the present invention is directed to
25 utilizing a principal advantage of relying on standard optical disc readers for laser
microscopic detection. This advantage includes the ubiquitous distribution of such
drives in the current consumer environment. Therefore, it would be desirable to provide
methods and apparatus for detecting operational and investigational structures on an
optical disc assembly without having to physically modify the processing circuitry
30 therein.

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May 18, 2001
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SUMMARY OF THE INVENTION

The present invention solves this and other limitations of the prior art by providing methods and apparatus for detecting investigational structures or features on an optical disc using a conventional disc drive. According to one embodiment of the present invention, one or more signal processing circuits within the conventional disc drive is programmably configured to function as an analog to digital (A/D) converter. The A/D converter is used to detect an electronic profile associated with investigational features and structures disposed on a surface of the optical disc assembly. The profiles may be used to determine the relative size, composition, and location of the detected structures.

Many different signals from the drive may be utilized to render the desired electronic profiles. Different electronic signals available within the drive may result in different electronic profiles or "signatures" for the same investigational feature. It is understood, however, that each such signature is unique and thus may be used as a separate and distinct indicator of the respective investigational feature under consideration. The conventional disc drive may then be programmably returned to its original operating configuration. Processing and imaging software both internal and external to the drive are related aspects of this embodiment of the present invention.

In accordance with another embodiment of this invention, and as an alternative to programmably configuring one or more signal processing circuits within the disc drive to function as an analog to digital (A/D) converter, an external buffer card and/or an A/D converter are employed. In these embodiments of the present invention, many different signals from the drive may also be employed to render the desired electronic profiles. As in the prior embodiment, different electronic signals available within the drive may result in different electronic profiles or "signatures" for the same investigational feature.

It is also understood relative to this embodiment of the present invention, that each such signature is unique and thus may be used as a separate and distinct indicator of the respective investigational feature or attribute thereof under consideration. Processing and imaging software are also related aspects of this embodiment of the present invention.

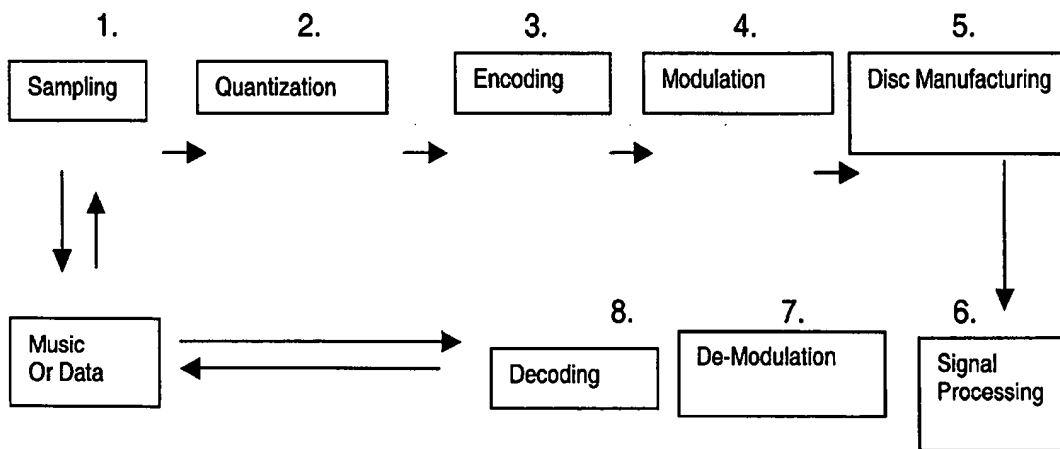
The structures, features, characteristics, and attributes which are investigated according to the present invention may include biological, chemical, or organic

specimens, test samples, investigational objects such as parts of insects or organic material, and similar test objects or target samples. Such structures, features, and attributes may also include specific chemical reactions and the products and by-products resulting therefrom such as, for example, any one of a variety of different colorimetric assays. In the case of an optical bio-disc, the material applied to the disc for investigation and analysis may include biological particulate suspensions and organic material such as blood, urine, saliva, amniotic fluid, skin cells, cerebrospinal fluid, serum, synovial fluid, semen, single-strand and double-strand DNA, pleural fluid, cells from selected body organs or tissue, pericardial fluid, feces, peritoneal fluid, and calculi. In the case of some of these materials, a reporter may be employed for detection purposes. These reporters include plastic micro-spheres or beads made of, for example, latex or polystyrene and colloidal gold particles with coatings of biomolecules that have an affinity for a given material such as a biotine molecule in a strand of DNA. Appropriate coatings include those made from streptavidin or neutravidin, for example. In this manner, objects too small to be detected by the read beam of the drive, may still be detected by association with the reporter.

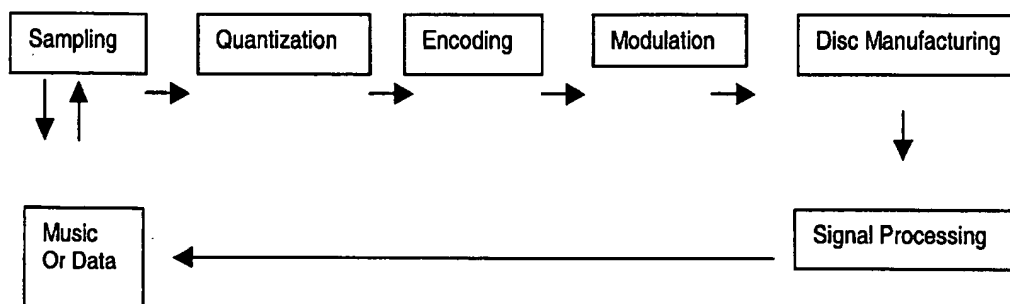
The optical bio-disc may be implemented on an optical disc including a format such as CD, CD-R, or DVD or a modified version thereof. The bio-disc may include encoded information for performing, controlling, and post-processing the test or assay. For example, such encoded information may be directed to controlling the rotation rate of the disc. Depending on the test, assay, or investigational protocol, the rotation rate may be variable with intervening or consecutive sessions of acceleration, constant speed, and deceleration. These sessions may be closely controlled both as to speed and time of rotation to provide, for example, mixing, agitation, or separation of fluids and suspensions with agents, reagents or antibodies. A disc drive assembly is employed to rotate the disc, read and process any encoded information stored on the disc, and analyze the liquid, chemical, biological, or biochemical component in an assay zone of the disc. The disc drive assembly may also be utilized to write information to the bio-disc either before or after the material in the assay zone is analyzed by the read beam of the drive.

According to a first embodiment of the present invention, an optical disc drive chipset is employed as an A/D converter to identify investigational features and structures, and thereafter to characterize such features and structures as unique signal elements or electronic signatures. An optical disc decoding system may be modified in such a way that some functionality in the system is removed. The removal of specific features from the decoding path of an optical disc decoder will provide a raw digital signal that effectively characterizes and uniquely identifies investigational features positioned on the surface of the optical bio-disc, on a substrate within the disc, or residing within a chamber or channel formed as a fluidic element of the disc assembly.

The decoding path in an optical disc system can be described by the following process:



The path may be modified to remove the Demodulation and Decoding operations and provide a raw signal to a computer.



A recordable master may contain operational features that are designed for use during the recording operation and not the reading operation. Table 1 below summarizes these operational differences.

TABLE 1

Disc Type	Function	Recording Properties	Reading or Playback Properties
CD-R CD-RW	Focus	Surface Properties	Surface Properties
	Tracking	22.05KHz Wobbled Groove	Pits or Marks
	Synchronization (Speed Control)	22.05KHz Wobbled Groove	Pit Patterns (Marks)
DVD-R DVD-RW DVD-RAM DVD+RW	Focus	Surface Properties	Surface Properties
	Tracking	140 or 160KHz Wobbled Groove	Pits or Marks
	Synchronization (Speed Control)	140 or 160KHz Wobbled Groove	Pit Patterns (Marks)

As indicated above, the decoder or servo system of a CD, CD-R or DVD player can be used to provide count, correlation, or characterization of a chemical response in the focal or operational feature plane of a disk. Other responses or raw signals from the drive chipset that quantify the signal magnitudes from an investigational feature or signal producing element include the high frequency signal (HF) (AC or DC coupled), the tracking error signal (TE), the focus error signal (FE), the Automatic Gain Control Setting (AGC), the push-pull tracking signal ((B+C)-(A+D)), the CD tracking signal (E-F), the CDR tracking signal ((A+D)-(B+C)), the focus signal ((A+D)-(B+D)), the differential phase detector signal (DPD) ((A+B)-(C+D)), the power monitor signal from the back of the laser, and the audio signal. Additional signals which may be employed with the present invention include the individual signals from the quad detector, A, B, C, and D, or side detectors E and F. In addition, the methods of the present invention may also be advantageously utilized in conjunction with array detectors currently becoming

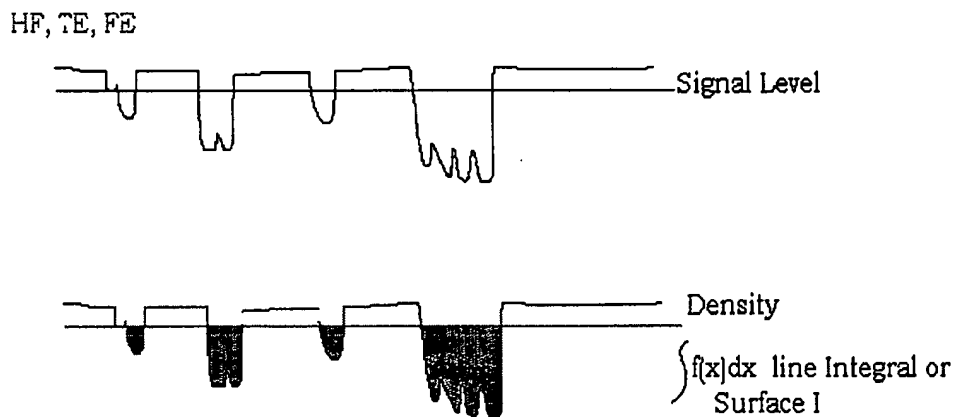
available in the market. These arrays include, for example, individual signals A, B, C, D, E, F, G, . . . Z. Each of these signals, or combinations thereof, may be advantageously employed according to the different embodiments of this invention to obtain the desired electronic profiles or signatures that uniquely characterize the

5 investigational feature or attribute of interest. The following discussion relating to Illustrations 1-6 presented hereinbelow, thus may apply to any of the various embodiments according to this invention.

The investigational features such as reporters or blood cells, for example, produce a signal level or density change relative to the signal produced by reading

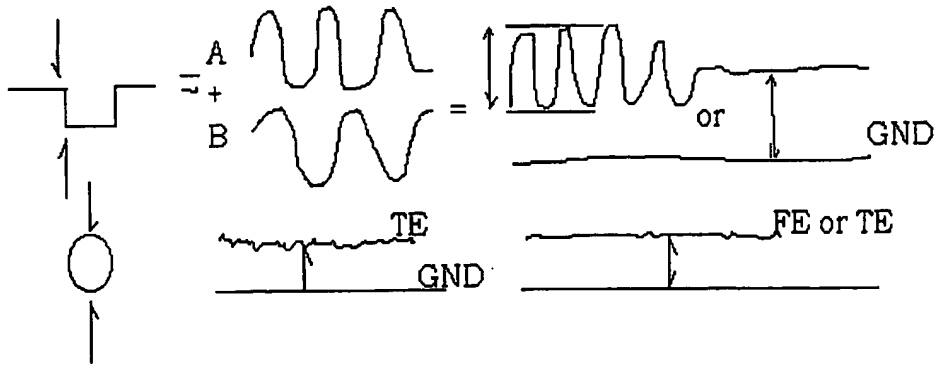
10 information encoded on the disc. The following graphical illustration represents the relative displacement of the data signal when the read beam of the drive encounters an investigational feature on or in the disc. The data signal may be the HF signal, the tracking error signal, the focus error signal, or one or more of a variety of other different signals such as those identified above.

ILLUSTRATION 1



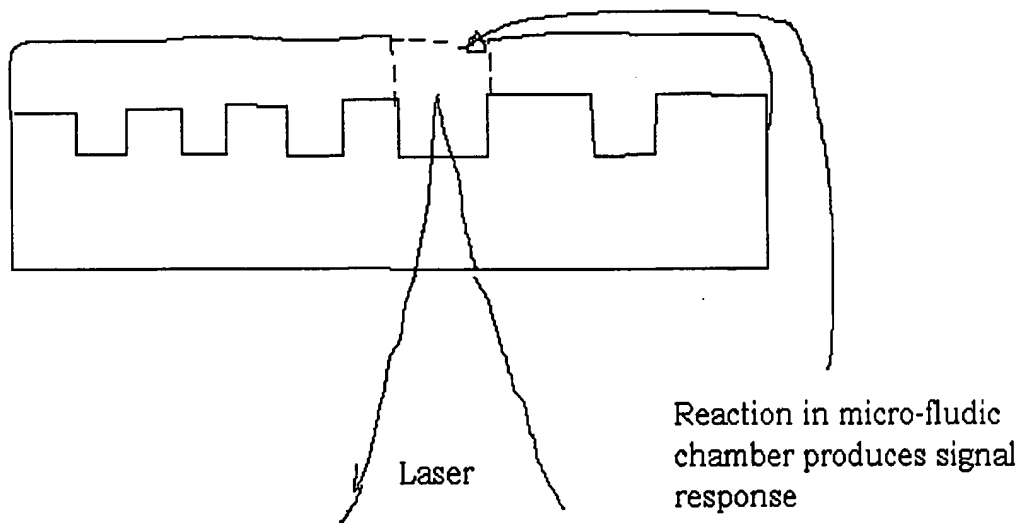
As indicated above, a change in an "operational" feature such as a groove, pit, or land, produces a change in signal level, signal jitter, or error rate. This is represented below in Illustration 2.

ILLUSTRATION 2



An increase or decrease in reflectivity is produced when the incident beam interacts with the disc. This change in reflectivity can be monitored by a corresponding change in the Automatic Gain Control ("AGC") setting which is output at the drive port. Thus in accordance with the present invention, when an investigational feature is encountered by the read or "interrogation" beam of the drive, a change in return light is monitored. Such investigational features may include a chemical reaction taking place in a micro-fluidic channel formed on or in the disc. This aspect of the present invention is graphically illustrated below.

ILLUSTRATION 3

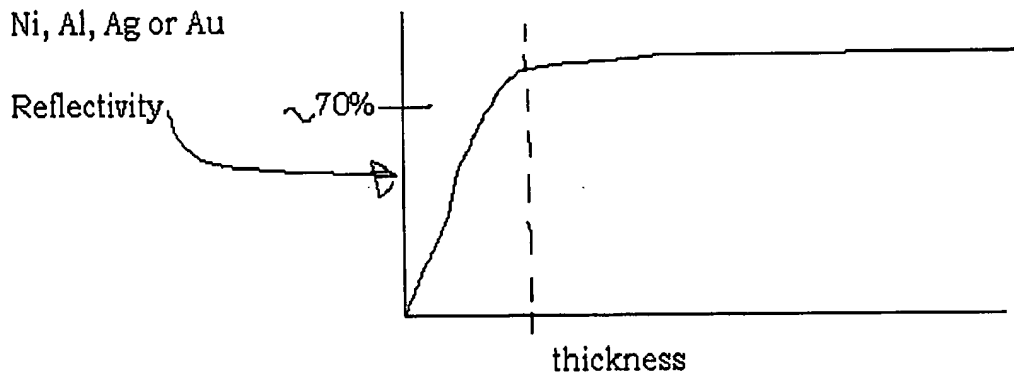


As a general matter relating to certain specific aspects of the present invention, the following illustration is presented to indicate that the reflectivity of a metal layer is a

function of the thickness of the layer up to a certain threshold thickness. For a metal thickness equal thereto or greater than such a threshold thickness, the reflectivity is unchanging and remains essentially constant at between about 80% and close to 100% depending on the metal and surface condition.

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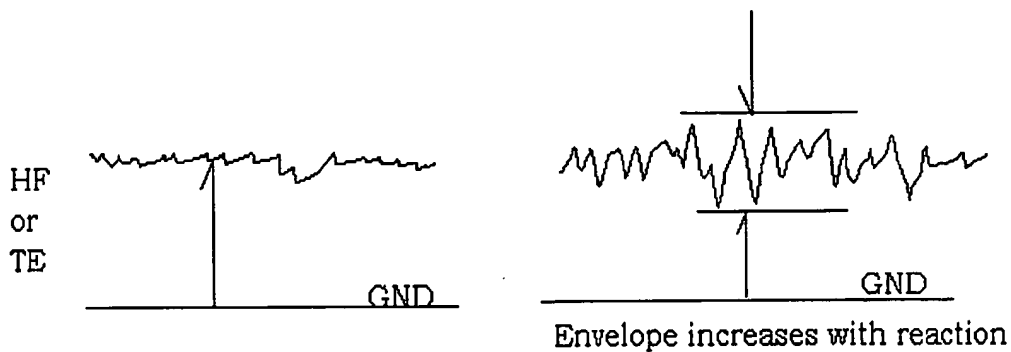
ILLUSTRATION 4



The next illustration represents the relative change in the HF or TE signal, for example, when the interrogation beam of a disc drive traverses across a chemical reaction occurring in or on the disc as represented above in Illustration 3.

ILLUSTRATION 5

Signal level increases or decreases with reaction.

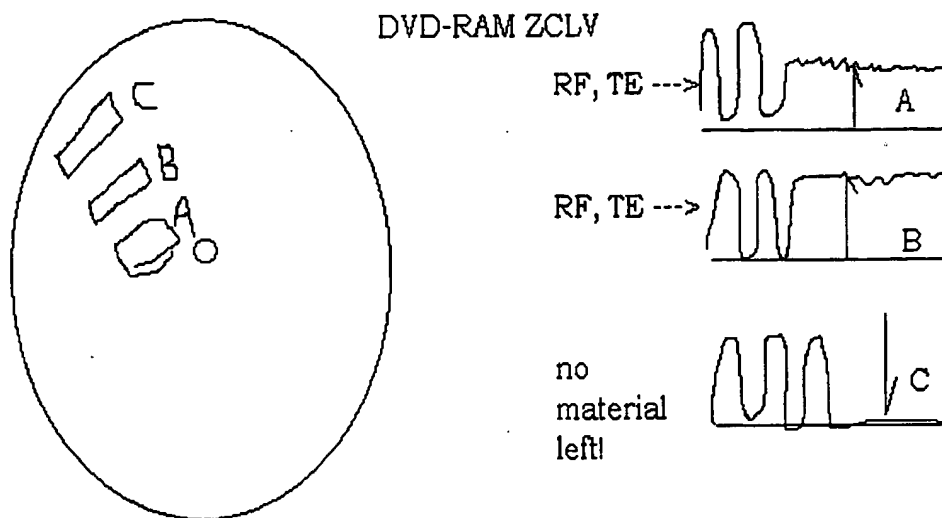


According to another aspect of the present invention, pits, marks, or grooves on

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a disc can be made of a chemically interactive material. The level of degradation in the material can determine some assay characteristic by providing a change in signal response. Chemistry or assay material can react with the reflective layer and reduce or enhance light transmitted, reflected, refracted, or absorbed according to the change in reflectivity of the reflective or metal layer shown in Illustration 4. For example, operational structures may be made of a nitrated cellulose material. In one implementation, chemical interactions may change the shape and/or thickness of operational structures and thus reduce signal response. Also the Ph of the solution may cause a deposition of metal on the surface of a zone in the disc and produce an increase in localized reflectivity. In another implementation, localized reaction may cause the removal of metallic material from the reflective surface. The removal of the material will cause a point of contrast in the signal. The response may be an analog signal characterization or an error rate distribution. Additionally, zones may be designed into the disc for differing concentrations and reactions. In these embodiments, the material is designed in such a way as to degrade at a specific concentration or reaction level. Illustration 6 below generally represents these aspects of the present invention. The disc in Illustration 6 includes three zones A, B, and C that are formed, for example, on a DVD-RAM disc with Zoned Constant Linear Velocity, (ZCLV). Zone C included a reaction according to this aspect of the present invention where the reflective layer was removed, while in zones A and B no such metal-removing reaction occurred. The resulting signal traces of, for example, the RF or TE signals are also shown.

ILLUSTRATION 6



According to yet further embodiments of this invention, the audio output of the drive may be utilized, modified, or augmented to produce a sound when the interrogation beam of the drive encounters an investigational feature or attribute. For example, the disc may be pre-recorded with digital silence and a sound produced when the read beam "reads" or detects an investigational feature. In this manner, different investigational features may produce discernibly different sounds or tones. Alternatively, the disc may included a sound track which would be interrupted by the formation or presence of an investigational feature blocking the encoded sound information. These sound or audio aspects of the present invention may be achieved by several and various embodiments and additional aspects of the present invention. These embodiments of the present invention may be generally grouped into three different categories, approaches, or techniques. The first includes using the existing sound card that is currently available in many drive assemblies. The second approach is directed to internally modifying the audio circuitry that exists in such current drive assemblies. And the third alternative approach or technique, is to provide an external sound module that interfaces with the disc drive assembly, an audio output device such as a pair of speakers, and processing software according to the present invention.

BRIEF DESCRIPTION OF THE DRAWING

Further objects of the present invention together with additional features contributing thereto and advantages accruing therefrom will be apparent from the following description of the preferred embodiments of the invention which are shown in the accompanying drawing figures with like reference numerals indicating like components throughout, wherein:

Fig. 1 shows a cross-sectional view of typical single-layer CD or CD-like disc and a schematic representation of a reader associated therewith;

Fig. 2 illustrates a side cross-sectional view of the disc shown in Fig. 1 at greater magnification;

Fig. 3 is a perspective view of the surface of a CD-R disc with wobble grooves;

Fig. 4 is a schematic representation of an optical disc detector and associated electronics that use three beams for tracking, focusing, and reading;

Fig. 5 illustrates the position of beams from a typical three-beam pickup relative to a track on an optical disc;

Fig. 6 is a block diagram of a prior art optical disc reader;

Fig. 7 is a functional block diagram of a conventional digital signal processing circuit;

Fig. 8 is a pictorial representation and block diagram illustrating alternate embodiments of the present invention directed to processing the high frequency, tracking, focusing, audio, or other signals of a disc drive and displaying or outputting results relating thereto;

Fig. 9 is a cross sectional side view of an optical disc assembly including a light-refractive cover and investigational features according to the present invention;

Fig. 10 is a view similar to Fig. 8 showing the optical disc assembly and investigational features of Fig. 9 in conjunction with the optical components and return beam of an optical disc reader and drive implemented according to a first embodiment of the present invention;

Fig. 11 is a top plan view of an optical disc drive assembly with the housing removed to show the spindle, the carriage assembly, the optical head assembly, and

the ribbon cable or connector which transmits signals to and from the optical head assembly;

Fig. 12 is a bottom perspective view of the optical disc drive assembly of Fig. 11, illustrating the physical layout of the chip set, related electronic circuitry, and the ribbon
5 connector from the head assembly as unplugged from the circuitry;

Fig. 13 is a top perspective view of an external buffer card adapted to receive signals from the head assembly of the drive buffer according to a first embodiment of the present invention;

Fig. 14 is a perspective view of an alternate embodiment of the external buffer
10 card illustrated in Fig. 13;

Fig. 15 is a block diagram illustrating the prior art optical disc reader of Fig. 6 as connected to the buffer card according to different embodiments of this invention;

Fig. 16 is a graphical representation illustrating the relationship between Figs. 16A, 16B, and 16C;

Figs. 16A, 16B, and 16C are electrical schematics of the amplifier stages according to a first embodiment of the buffer cards shown in Figs. 13 and 14;

Fig. 17 is a cross-sectional side view of an optical bio-disc including bead reporters as utilized in conjunction with the present invention;

Fig. 18A is a graphical representation of two 6.8 μm blue beads positioned relative to the tracks of an optical bio-disc according to the present invention;

Fig. 18B is a series of signature traces derived from the beads of Fig. 18A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention;

Fig. 19A is a graphical representation of two 6.42 μm red beads positioned
25 relative to the tracks of an optical bio-disc according to the present invention;

Fig. 19B is a series of signature traces derived from the beads of Fig. 19A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention;

Fig. 20A is a graphical representation of two 6.33 μm polystyren beads
30 positioned relative to the tracks of an optical bio-disc according to the present invention;

Fig. 20B is a series of signature traces derived from the beads of Fig. 20A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention;

Fig. 21A is a graphical representation of a 5.5 μm glass bead positioned relative to the tracks of an optical bio-disc according to the present invention;

Fig. 21B is a series of signature traces derived from the bead illustrated in Fig. 21A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention;

Fig. 22A is a graphical representation of 4.5 μm magnetic bead positioned relative to the tracks of an optical bio-disc according to the present invention;

Fig. 22B is a series of signature traces derived from the bead of Fig. 22A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention;

Fig. 23A is a graphical representation of two 4.0 μm blue beads positioned relative to the tracks of an optical bio-disc according to the present invention;

Fig. 23B is a series of signature traces derived from the beads of Fig. 23A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention;

Fig. 24A is a graphical representation of a 2.986 μm polystyrene bead positioned relative to the tracks of an optical bio-disc according to the present invention;

Fig. 24B is a series of signature traces derived from the bead illustrated in Fig. 24A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention;

Fig. 25A is a graphical representation of two 2.9 μm white beads positioned relative to the tracks of an optical bio-disc according to the present invention;

Fig. 25B is a series of signature traces derived from the beads of Fig. 25A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention;

Fig. 26A is a graphical representation of four 2.8 μm magnetic beads positioned relative to the tracks of an optical bio-disc according to the present invention;

Fig. 26B is a series of signature traces derived from the beads of Fig. 26A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention;

Fig. 27A is a graphical representation of a mixture of beads including 2.8 μm magnetic beads, 4.0 and 6.8 μm blue polystyrene beads, and different sized silica beads positioned relative to the tracks of an optical bio-disc according to the present invention;

Fig. 27B is a series of signature traces derived from the beads of Fig. 27A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention;

Fig. 28A is a graphical representation of two 2.9 μm white fluorescent polystyrene beads positioned relative to the tracks of an optical bio-disc according to the present invention;

Fig. 28B is a series of signature traces derived from the beads of Fig. 28A utilizing a DC coupled and buffered HF signal from the optical drive according to the present invention;

Fig. 29A is a graphical representation of two 2.9 μm white fluorescent polystyrene beads positioned relative to the tracks of an optical bio-disc according to the present invention;

Fig. 29B is a series of signature traces derived from the beads of Fig. 29A utilizing a DC coupled and buffered "A" signal from the optical drive according to the present invention;

Fig. 30 is a cross-sectional side view of an optical bio-disc including a proximally positioned red blood cell as the investigational feature interrogated by the read beam of the optical disc drive assembly according to the present invention;

Fig. 31A is a graphical representation of a proximally positioned red blood cell approximately 6.0 μm in diameter positioned relative to the tracks of an optical bio-disc according to the present invention;

Fig. 31B is a series of signature traces derived from the red blood cell of Fig. 31A utilizing a AC coupled and buffered HF signal from the optical drive according to the present invention;

Fig. 32A is a graphical representation of a proximally positioned red blood cell approximately 6.0 μm in diameter positioned relative to the tracks of an optical bio-disc according to the present invention;

5 Fig. 32B is a series of signature traces derived from the red blood cell of Fig. 32A utilizing a DC coupled and buffered HF signal from the optical drive according to the present invention;

Fig. 33 is a cross-sectional side view of an optical bio-disc including a distally positioned red blood cell as the investigational feature interrogated by the read beam of the optical disc drive assembly according to the present invention;

10 Fig. 34A is a graphical representation of two distally positioned red blood cells approximately 6.0 μm in diameter positioned relative to the tracks of an optical bio-disc according to the present invention;

15 Fig. 34B is a series of signature traces derived from the red blood cells of Fig. 34A utilizing a AC coupled and buffered HF signal from the optical drive according to the present invention;

Fig. 35A is a graphical representation of two distally positioned red blood cells approximately 6.0 μm in diameter positioned relative to the tracks of an optical bio-disc according to the present invention;

20 Fig. 35B is a series of signature traces derived from the red blood cells of Fig. 35A utilizing a DC coupled and buffered HF signal from the optical drive according to the present invention;

Fig. 36 is a top view an optical inspection disc with the top cap removed to illustrate a gnat's wing positioned in an inspection channel according to the present invention;

25 Fig. 36A is an enlarged top view of the indicated portion of Fig. 36 showing in greater detail the gnat's wing, inspection channel, and information storage tracks of the optical inspection disc according to this embodiment of the present invention;

Fig. 37 is a cross-sectional side view taken perpendicular to a radius of the optical inspection disc of Fig. 36 including the gnat's wing as the investigational feature
30 interrogated according to the present invention by the read beam of an optical disc drive assembly;

Fig. 38A is a graphical representation of a lateral section of the gnat's wing of Fig. 36 as positioned in the inspection channel relative to the tracks of an optical inspection disc according to the present invention;

Fig. 38B is a single signature trace derived from the section of the gnat's wing of Fig. 38A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention;

Fig. 39A is a graphical representation similar to that shown in Fig. 38A;

Fig. 39B is a series of four consecutive signature traces derived from the section of the gnat's wing of Fig. 39A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention;

Fig. 40A is a graphical representation similar to that shown in Fig. 38A;

Fig. 40B is a series of consecutive signature traces at moderate density derived from the section of the gnat's wing of Fig. 40A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention;

Fig. 41A is a graphical representation similar to that shown in Fig. 38A;

Fig. 41B is a series of consecutive signature traces at higher density derived from the section of the gnat's wing of Fig. 41A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention;

Figs. 42A, 42B, and 42C are pictorial representations of the gnat's wing of Fig. 36 as rendered by methods according to the present invention respectively utilizing either an AC coupled and buffered HF signal, a DC coupled and buffered "A" signal, or a DC coupled and buffered HF signal from an optical drive assembly;

Fig. 43 is a graphical representation illustrating the relationship between Figs. 43A, 43B, and 43C;

Figs. 43A, 43B, and 43C are electrical schematics of a second embodiment of the amplifier stages that may be implemented according to the present invention in the buffer cards shown in Figs. 13 and 14;

Fig. 44 is a top view of a circuit board including a triggering detection assembly according to another aspect of the present invention;

Fig. 45 is an electrical schematic of the triggering circuit shown in Fig. 44;

Fig. 46 is a functional block diagram of a digital signal processing circuit programmably configured as an analog to digital converter in accordance with the principles of an alternate embodiment of the present invention as represented in Fig. 8; and

- 5 Fig. 47 is a flow chart illustrating some of the steps involved in detecting investigational elements in accordance with the second embodiment of the present invention illustrated in Fig. 46.

Brief Description of a Conventional Optical Disc Reader and Disc

- 10 To provide some background for further discussion of the present invention, relevant features of a conventional optical disc reader and optical disc are described briefly in connection with Figs. 1-7. Fig. 1 depicts the reader's optical pickup or objective assembly 10 and a conventional CD-type optical disc 11 with a light path indicated as dashed lines. For clarity, Fig. 1 depicts a minimal complement of the optical pickup components. Fig. 2 provides a side cross-sectional enlarged view of disc 11 in the same orientation relative to the incident light.

15 With reference to Figs. 1 and 2, the optical pickup 10 includes light source 19, lenses 12, 13, and 14, beam splitter 15, quarter wave plate 20, and detector 18. Light source 19, typically a laser diode or light emitting diode, emits a light beam which is collimated by lens 12. The collimated beam is then reflected toward optical disc 11 by beam splitter 15. Objective lens 13 focuses the light beam onto a small spot on the light-proximal, or first, surface 113 of optical disc 11. By convention, disc layers are numbered upwards from light-proximal to light-distal surfaces.

- 20 The light beam is refracted down to focus on reflective surface 114 (also termed second surface) of the disc and returned through objective lens 13 and quarter wave plate 20 to beam splitter 15. Quarter wave plate 20 changes the polarization of the light beam so that beam splitter 15 directs the reflected beam through lens 14, which focuses the reflected beam onto detector 18. Astigmatic element 16, which may be a cylindrical lens, may be included between beam splitter 15 and detector 18 to introduce
25 astigmatism in the reflected light beam.
30

As shown in greater detail in Fig. 2, CD-type disc 11 includes three layers from light-proximal to light-distal. These layers include a transparent substrate 112, a reflective layer 114, and a protective layer 116. Transparent substrate 112 makes up most of the thickness of a typical CD-type disc, as measured along the optical axis, and provides both optical and structural features necessary for disc operation. Substrate layer 112 is typically impressed or embossed with a spiral track that starts at the innermost readable portion of the disc and then spirals out to the outermost readable portion of the disc. In a non-recordable disc, this track is made up of a series of embossed pits, each typically having a depth of approximately one-quarter the wavelength of the light that is used to read the disc. The pits have varying lengths. The length and spacing of the pits is employed as the mechanism for encoding the data.

With reference now to Fig. 3, the spiral groove in a recordable disc contains a dye rather than pits. A typical recordable disc includes a spiral groove having a characteristic shape along the length thereof. This type of groove is known as a "wobble groove". The wobble groove is formed by a bottom portion having undulating or wavy side walls. A raised or elevated portion separates adjacent grooves in the spiral. Such a wobble groove may then include an embossed portion 110 and a groove portion 118 as shown in Fig. 3. The embossed portion 110 and the groove portion 118 are similar to the wobble groove found on a standard recordable CD.

Referring now to Fig. 4, a detector 18 and its associated electronics are described in more detail. Detector 18 typically includes a central detector, and can be bordered by additional detector elements. The central detector may be split into multiple detector elements (e.g., four) and arranged as shown in Fig. 4. Detector elements A to F (sometimes collectively referred to as a "quad detector") each provide an electrical signal indicative of the intensity of the reflected light beam striking that element.

Typically, a CD drive uses a three-beam pickup, in which the light beam is split into three beams, a main beam and two tracking beams. The main beam is focused onto the surface of an optical disc so that it is centered on a tracking structure, whereas the tracking beams fall on the opposite sides of the tracking structure. For example, Fig. 5 shows a main beam 21 centered on track 24 (as defined by pits 22), and tracking

beams 23 falling on opposite sides of track 24. By design, the three beams are reflected from the optical disc and directed to detector 18, Fig. 4, so that main beam 21 falls on the quad detector, and tracking beams 23 fall on sensor elements E and F.

5 The sum of the signals from the quad detector, e.g., $A + B + C + D$, provides a radio frequency (RF) signal, also referred to as a high frequency (HF), quad-sum, or sum signal. As used herein the notation " $A + B$ " indicates the sum of the signals from detector elements A and B. The RF (i.e., HF, quad-sum, or sum) signal is typically demodulated to recover data recorded on the optical disc.

10 Various pairs of the signals from detector elements A to F are also combined to provide feedback signals for tracking and focus control. For example, a tracking (tracking error, or TE) signal may be obtained from the difference between the E and F signals, (i.e., $E - F$). And, because of astigmatism introduced by astigmatic element 16, a focus error (FE) signal may be obtained from the difference between the $A + C$ and $B + D$ signals.

15 The circuitry of Fig. 4 is just one example of circuitry that provides focus and tracking error signals in an optical disc player. Numerous methods are known for providing these signals. For example, a focus error signal may be obtained by the critical angle method, described in U.S. Patent No. 5,629,514 or the Foucault and astigmatism methods, described in *The Compact Disc Handbook* by Pohlmann, A-R Editions, Inc. (1992) which are incorporated by reference in their entireties. Similarly, tracking error signals may be obtained using the single beam push-pull or three beam methods described in *The Compact Disc Handbook*, the differential phase method described in U.S. Patent No. 5,130,963, which is incorporated by reference in its entirety, or the single beam high frequency wobble method.

25 The RF signal, obtained from summing the signals from all of detector elements A, B, C, and D, is normally processed to extract whatever data is recorded on the optical disc. First, the analog RF signal is conditioned, with normalization and equalization performed. Next, the analog signal is converted to a digital signal including a serial stream of digital data referred to as channel bits. The channel bit stream is then
30 demodulated according to the modulation standard used for the type of optical disc being read. For example, it is common for CD-type discs to use eight-to-fourteen (also

denominated "eight-of-fourteen") modulation (EFM) wherein a data byte, or eight data bits, are encoded in fourteen channel bits. There are three merging bits between each group of fourteen channel bits. Thus, when reading a CD-type optical disc, seventeen channel bits are read from the optical disc, the merging bits are discarded, and the remaining fourteen bits are decoded, or demodulated, to obtain the original data byte. The data bytes themselves are grouped into blocks, which are further processed to reduce the effects of disc defects, such as scratches on the disc surface.

Typically, such processing is performed by analog circuitry in combination with one or more integrated circuit chips. Often, the circuitry takes the form of a special chip set or a single ASIC (application-specific integrated circuit) chip.

Fig. 6 is generalized block diagram of an illustrative chip set for a typical optical drive system. Although the chip sets for CD, CD-R, and DVD drives can be somewhat different from one another, it will be understood that the system shown in Fig. 6 is meant to generically represent all types of optical drives, and that a detailed understanding of the differences between the chip sets is not necessary to practice the present invention.

In Fig. 6, the RF signal from detector 18, Fig. 4, may be converted to a square wave by comparator 31, which provides a high output when the RF signal is above a threshold level, and a low output when the RF signal is below the threshold.

Digital signal processing circuit (DSP) 32 then samples the resulting square wave signal to determine the value of each channel bit. DSP 32 further demodulates the channel bits to extract the data bytes which are then grouped into blocks and processed to correct errors that may have occurred. Memory 33a provides temporary storage for the data as it is being processed by DSP 32 and assembled into blocks.

Servo block 34 analyzes the tracking error (TE) signal (or a wobble tracking error (WTE) in a DVD or CD-R system) and provides a tracking control signal to the tracking mechanisms to ensure the pickup assembly maintains proper tracking. Similarly, a focus control signal is provided based on focus error signal FE. DSP 32 provides an indication of the data rate of the RF signal which is used by servo block 34 to provide a speed control signal to the spindle motor of the optical disc drive.

In an audio CD player, after processing by DSP 32, each data block is sent to audio reproduction circuitry not shown in Fig. 6. However, in some data storage applications, each data block may contain additional error detection codes (EDC) and error correction codes (ECC). EDC/ECC circuitry 35 typically uses the EDC and ECC codes to increase the integrity of the data block by detecting and correcting errors not already corrected by DSP 32. Memory 33b, which may be combined with memory 33a, provides temporary storage for data blocks being processed by EDC/ECC circuitry 35.

Finally, the data blocks are transferred from the optical disc player to host 37 by means of interface circuitry 36. Although an ATAPI interface is shown, it will be understood that other interfaces, such as SCSI, Firewire, or Universal Serial Bus (USB), and the like could also be used.

Controller 38 coordinates the operation of the various components of chip set 30, for example, by coordinating the transfer of data blocks between DSP 32 and EDC/ECC circuitry 35. Controller 38 also keeps track of which data block is being read and may keep track of various parameters indicative of the operational status of the optical disc reader.

Program memory 39 contains program code for the operation of controller 38. In many optical disc reader chip sets, program memory 39 may also contain program instructions for DSP 32 or EDC/ECC circuitry 35. This is advantageous for manufacturers in that the operation of the disc drive may be changed by altering the program code in program memory 39. For example, a newly developed method of modulating or encoding data on an optical disc may be accommodated by changing program memory 39.

Fig. 7 shows a functional block diagram illustrating the relatively complex signal processing that occurs within DSP chip 32 when configured in a conventional manner. As shown, DSP 32 performs several functions. For example, DSP 32 typically equalizes and/or normalizes the RF signal (block 40); converts the normalized RF signal from the analog to digital (block 42); demodulates and decodes the resulting EFM signal (block 44); performs some type of error checking procedure (e.g., using Cross-Interleaved Reed-Solomon Code "CIRC" block 46); and provides the resulting signal to an output interface for communication with the host data bus 37 (block 48). Examples

of commonly used DSP chips that perform some or all of these functions include the SAA 7210, SAA 7220, and the SAA 7735, available from Philips Electronics Corporation, Eindhoven, Netherlands.

While the foregoing description is sufficient for a basic understanding of the present invention, there are numerous alternative designs and configurations of an optical pickup and associated electronics which may be used in the context of the present invention. Further details and alternative designs are described in *Compact Disc Technology*, by Nakajima and Ogawa, IOS Press, Inc. (1992); *The Compact Disc Handbook, Digital Audio and Compact Disc Technology*, by Baert et al. (eds.), Books Britain (1995); *CD-Rom Professional's CD-Recordable Handbook: The Complete Guide to Practical Desktop CD*, Starrett et al. (eds.), ISBN:0910965188 (1996); which are incorporated herein in their entirety by this reference.

Detailed Description of the Invention

Referring now to Fig. 8, there is shown an optical disc drive 140 according to the present invention. The optical disc drive 140 is adapted to receive a disc 130 of a type designed to accommodate a wide variety of investigational features. The disc 130 may be an optical bio-disc such as those disclosed in commonly assigned U.S. Provisional Application Nos. 60/252,726 entitled "Bioactive Solid Phase for Specific Cell Capture and Optical Bio-Disc Including Same"; 60/249,391 entitled "Optical Disc Assembly for Performing Microscopy and Spectroscopy Using Optical Disc Drive"; and 60/257,705 entitled "Surface Assembly for Immobilizing DNA Capture Probes and Bead-Based Assay Including Optical Bio-Discs and Methods Relating Thereto". In one embodiment of the present invention, the unprocessed HF signal is tapped from the optical disc drive 140 and directed to a modified personal computer or PC 142. The PC 142 includes software and/or hardware for processing the HF signal generated from the read beam of the optical drive 140 which is modulated as a function of encountering investigational features on or in any one or more of a number of different layers, substrates, or surfaces forming the disc 130. The same read beam is also modulated in a conventional manner by encountering or reading operational features in the disc 130. Such operational features typically include pits and lands as in a pre-recorded CD-like

disc or marks and spaces formed by dyed and undyed areas in a recordable disc such as a CD-R. The pits and lands, or marks and spaces embody encoded information in the nature of data, video, and/or audio according to any one of a number of schemes for encoding such information. The PC 142 may include a monitor 146 and speakers 148.

- 5 After the raw HF signal is processed by the PC 142 in a desired manner, characteristic aspects of the investigational feature may be displayed on the monitor 146. Thus the monitor 146 and speakers 148 may, respectively, also be employed to display conventional video or audio encoded on the disc 130. This embodiment of the present invention will be hereinafter referred to as the "modified PC embodiment" for purposes
- 10 of convenience and clarity.

In an alternate embodiment of the present invention illustrated in Fig. 8, the disc drive 140 includes a programmable DSP 152 and an analyzer 154 instead of a PC including software and/or hardware implemented to accommodate analysis of investigational features. Aspects of this alternate embodiment are described in further detail herein below. For purposes of convenience and clarity, this embodiment of the present invention will hereinafter be referred to as the "DSP embodiment".

According to yet another alternate embodiment of this invention, a tap-off of the HF signal from the drive 140 may be directed to an external analog-to-digital converter 156 as shown in Fig.8. Alternatively, any one of a variety of different signals or signal combinations may be tapped off the drive 140 as illustrated. Aspects of this alternate embodiment are also described in further detail herein below. For purposes of convenience and clarity, this embodiment of the present invention will hereinafter be referred to as the "A to D embodiment". The A to D embodiment may be modified to include an external buffer card 152.

- 25 Any one of the above embodiments may alternatively utilize either the tracking error signal (TE) or the focus error signal (FE). In addition, other signals such as the high frequency signal (HF) (AC or DC coupled), the Automatic Gain Control Setting (AGC), the push-pull tracking signal $((B+C)-(A+D))$, the CD tracking signal (E-F), the CDR tracking signal $((A+D)-(B+C))$, the focus signal $((A+D)-(B+D))$, the differential
- 30 phase detector signal (DPD) $((A+B)-(C+D))$, the power monitor signal from the back of the laser, or the audio signal may be employed. Additional signals which may be

utilized with the present invention include the individual signals from the quad detector, A, B, C, and D, or side detectors E and F. The trend in current conventional drives is to use a high density photo detector array in place of the typical quad detector. The present invention may be readily implemented in these types of drives.

5 With continuing reference to Fig. 8, the audio output of the drive may be utilized, modified, or augmented to produce a sound when the interrogation beam of the drive encounters an investigational feature or attribute. For example, the disc may be pre-recorded with digital silence and a sound produced when the read beam "reads" or detects an investigational feature. In this manner, different investigational features may
10 produce discernibly different sounds or tones. Alternatively, the disc may included a sound track which would be interrupted by the formation or presence of an investigational feature blocking the encoded sound information. These sound or audio aspects of the present invention may be achieved by several and various embodiments and additional aspects of the present invention. These embodiments of the present
15 invention may be generally grouped into three different categories, approaches, or techniques. The first includes using the existing sound card that is currently available in many drive assemblies. The second approach is directed to internally modifying the audio circuitry that exists in such current drive assemblies. And the third alternative approach or technique, is to provide an external sound module 156 that interfaces with
20 the disc drive assembly, an audio output device such as a pair of speakers, and processing software according to the present invention.

All of the different embodiments illustrated in Fig. 8, except the modified PC embodiment, would typically include a conventional PC 158 for functionality described in further detail below.

25 Commonly assigned U.S. Patent Application No. 09/421,870 entitled "Trackable Optical Discs with Concurrently Readable Analyte Material (hereinafter the '870 application) discloses coupling an oscilloscope to the HF or RF signal for detecting the dual peak profiles associated with investigational structures while acquiring the encoded information needed to operate the disc drive. These peaks appear as a result of
30 changes in reflectance as the light beam traverses investigational structures or reporters on the optical disc surface. Such electronic profiles may be advantageously

used to detect and discriminate among structures under investigation. An external analog-to-digital (A/D) converter, such as converter 156, may be connected to the RF signal, for example, in order to determine the number of dual peaks encountered (and thus the number investigational structures or reporters) on any portion of the optical disc. The magnitude and/or duration of the digitized peak signals may be interpreted by an associated application program to determine the relative size, composition, and location of the detected structures.

The '870 application teaches that micron-sized investigational or "nonoperational" structures may be disposed upon a surface of an optical disc in a number of ways. One suitable embodiment for accomplishing this is depicted in Fig. 9. As shown in Fig. 9, light beam 137 is incident on the disc assembly from below. Disc 130 includes disc substrate 132 and reflective layer 134, upon which investigational structures or features 136 are disposed. Investigational structures or features 136 may include plastic microspheres or colloidal gold beads having bio-molecule coatings with an affinity for a particular type of biological material or sample under investigation. Wobble groove 138, impressed in substrate 132 and coated by reflective layer 134, is indicated in Fig. 9. Also shown is the nonintegral cover 140. Investigational structures 136 may be detected, measured, and characterized by the optical disc reader according to the present invention. The operational structures of the disc, including tracking features, may be detected concurrently (or nonconcurrently) with and readily discriminated from investigational structures using a single optical pickup.

Fig. 10 is a view similar to Fig. 8 showing the optical disc assembly and investigational features of Fig. 9 in conjunction with the optical components and return beam of an optical disc reader and drive implemented according to the A to D embodiment of the present invention. The optical bio-disc 130 includes a trigger mark 166.

Fig. 11 is a top plan view of an optical disc drive assembly with the housing removed to show the spindle, the carriage assembly, the optical head assembly, and the ribbon cable or connector which transmits signals to and from the optical head assembly.

Fig. 12 is a bottom perspective view of the optical disc drive assembly of Fig. 11, illustrating the physical layout of the chip set, related electronic circuitry, and the ribbon connector from the head assembly as unplugged from the circuitry.

Fig. 13 is a top perspective view of an external buffer card adapted to receive signals from the head assembly of the drive buffer according to the A to D embodiment of the present invention.

Fig. 14 is a perspective view of an alternate embodiment of the external buffer card illustrated in Fig. 13.

Fig. 15 is a block diagram illustrating the prior art optical disc reader of Fig. 6 as connected to the buffer card according to the different A to D embodiments of this invention. Chip set 30 according to the present invention is shown to include taps to the the A, B, C, and D outputs from the detector 18. Fig. 15 further illustrates that the F-, F+, T-, T+, HF-AC coupled, and HF-DC coupled signals may also be tapped from the RF matrix amplifier of the CD drive. These tapped signals provide access to unprocessed analog signals produced by detector 18 and the RF matrix amplifier. This permits external instrumentation to be connected to signals without interfering with normal drive operation. Such external instrumentation may alternatively include the modified PC 142, the audio processing module 156, the external analog-to-digital converter 156, or the external buffer 152 and external A/D converter 156 as shown in Fig. 8. As indicated above, Fig. 15 is directed to the A to D embodiment with external buffer card 150. Fig. 16 is a graphical representation illustrating the relationship between Figs. 16A, 16B, and 16C;

Figs. 16A, 16B, and 16C are electrical schematics of the amplifier stages according to a first embodiment of the buffer cards shown in Figs. 13 and 14.

Fig. 17 is a cross-sectional side view of an optical bio-disc including bead reporters as utilized in conjunction with the present invention.

Fig. 18A is a graphical representation of two 6.8 μm blue beads positioned relative to the tracks of an optical bio-disc according to the present invention. These beads were located on a disc similar to the disc shown in Fig. 17.

Fig. 18B is a series of signature traces derived from the beads of Fig. 18A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention.

Fig. 19A is a graphical representation of two 6.42 μm red beads positioned relative to the tracks of an optical bio-disc according to the present invention. These beads were located on a disc similar to the disc shown in Fig. 17.

Fig. 19B is a series of signature traces derived from the beads of Fig. 19A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention.

Fig. 20A is a graphical representation of two 6.33 μm polystyren beads positioned relative to the tracks of an optical bio-disc according to the present invention. These beads were located on a disc similar to the disc shown in Fig. 17.

Fig. 20B is a series of signature traces derived from the beads of Fig. 20A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention.

Fig. 21A is a graphical representation of a 5.5 μm glass bead positioned relative to the tracks of an optical bio-disc according to the present invention. These beads were located on a disc similar to the disc shown in Fig. 17.

Fig. 21B is a series of signature traces derived from the bead illustrated in Fig. 21A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention.

Fig. 22A is a graphical representation of 4.5 μm magnetic bead positioned relative to the tracks of an optical bio-disc according to the present invention. These beads were located on a disc similar to the disc shown in Fig. 17.

Fig. 22B is a series of signature traces derived from the bead of Fig. 22A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention;

Fig. 23A is a graphical representation of two 4.0 μm blue beads positioned relative to the tracks of an optical bio-disc according to the present invention. These beads were located on a disc similar to the disc shown in Fig. 17.

Fig. 23B is a series of signature traces derived from the beads of Fig. 23A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention.

Fig. 24A is a graphical representation of a 2.986 μm polystyrene bead positioned relative to the tracks of an optical bio-disc according to the present invention. These beads were located on a disc similar to the disc shown in Fig. 17.

Fig. 24B is a series of signature traces derived from the bead illustrated in Fig. 24A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention.

Fig. 25A is a graphical representation of two 2.9 μm white beads positioned relative to the tracks of an optical bio-disc according to the present invention. These beads were located on a disc similar to the disc shown in Fig. 17.

Fig. 25B is a series of signature traces derived from the beads of Fig. 25A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention.

Fig. 26A is a graphical representation of four 2.8 μm magnetic beads positioned relative to the tracks of an optical bio-disc according to the present invention. These beads were located on a disc similar to the disc shown in Fig. 17.

Fig. 26B is a series of signature traces derived from the beads of Fig. 26A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention.

Fig. 27A is a graphical representation of a mixture of beads including 2.8 μm magnetic beads, 4.0 and 6.8 μm blue polystyrene beads, and different sized silica beads positioned relative to the tracks of an optical bio-disc according to the present invention. These beads were located on a disc similar to the disc shown in Fig. 17.

Fig. 27B is a series of signature traces derived from the beads of Fig. 27A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention.

Fig. 28A is a graphical representation of two 2.9 μm white fluorescent polystyrene beads positioned relative to the tracks of an optical bio-disc according to the

present invention. These beads were located on a disc similar to the disc shown in Fig. 17.

Fig. 28B is a series of signature traces derived from the beads of Fig. 28A utilizing a DC coupled and buffered HF signal from the optical drive according to the present invention.

Fig. 29A is a graphical representation of two 2.9 μm white fluorescent polystyrene beads positioned relative to the tracks of an optical bio-disc according to the present invention. These beads were located on a disc similar to the disc shown in Fig. 17.

Fig. 29B is a series of signature traces derived from the beads of Fig. 29A utilizing a DC coupled and buffered "A" signal from the optical drive according to the present invention.

Fig. 30 is a cross-sectional side view of an optical bio-disc including a proximally positioned red blood cell as the investigational feature interrogated by the read beam of the optical disc drive assembly according to the present invention.

Fig. 31A is a graphical representation of a proximally positioned red blood cell approximately 6.0 μm in diameter positioned relative to the tracks of an optical bio-disc according to the present invention. The red blood cell illustrated in Fig. 31A was located on the type of the disc shown in Fig. 30.

Fig. 31B is a series of signature traces derived from the red blood cell of Fig. 31A utilizing a AC coupled and buffered HF signal from the optical drive according to the present invention.

Fig. 32A is a graphical representation of a proximally positioned red blood cell approximately 6.0 μm in diameter positioned relative to the tracks of an optical bio-disc according to the present invention. The red blood cell illustrated in Fig. 32A was located on the type of the disc shown in Fig. 30.

Fig. 32B is a series of signature traces derived from the red blood cell of Fig. 32A utilizing a DC coupled and buffered HF signal from the optical drive according to the present invention.

Fig. 33 is a cross-sectional side view of an optical bio-disc including a distally positioned red blood cell as the investigational feature interrogated by the read beam of the optical disc drive assembly according to the present invention.

Fig. 34A is a graphical representation of two distally positioned red blood cells approximately 6.0 μm in diameter positioned relative to the tracks of an optical bio-disc according to the present invention. The red blood cells illustrated in Fig. 34A were located on the type of the disc shown in Fig. 33.

Fig. 34B is a series of signature traces derived from the red blood cells of Fig. 34A utilizing a AC coupled and buffered HF signal from the optical drive according to the present invention.

Fig. 35A is a graphical representation of two distally positioned red blood cells approximately 6.0 μm in diameter positioned relative to the tracks of an optical bio-disc according to the present invention. The red blood cells illustrated in Fig. 35A were located on the type of the disc shown in Fig. 33.

Fig. 35B is a series of signature traces derived from the red blood cells of Fig. 35A utilizing a DC coupled and buffered HF signal from the optical drive according to the present invention.

Fig. 36 is a top view an optical inspection disc with the top cap removed to illustrate a gnat's wing positioned in an inspection channel according to the present invention. The optical inspection disc illustrated in Fig. 36 also includes a trigger mark 166. This trigger mark 166 provides the same function as the trigger mark 166 discussed in detail in conjunction with Fig. 10.

Fig. 36A is an enlarged top view of the indicated portion of Fig. 36 showing in greater detail the gnat's wing, inspection channel, and information storage tracks of the optical inspection disc according to this embodiment of the present invention.

Fig. 37 is a cross-sectional side view taken perpendicular to a radius of the optical inspection disc of Fig. 36 including the gnat's wing as the investigational feature interrogated according to the present invention by the read beam of an optical disc drive assembly.

Fig. 38A is a graphical representation of a lateral section of the gnat's wing of Fig. 36 as positioned in the inspection channel relative to the tracks of an optical inspection disc according to the present invention.

Fig. 38B is a single signature trace derived from the section of the gnat's wing of Fig. 38A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention.

Fig. 39A is a graphical representation similar to that shown in Fig. 38A.

Fig. 39B is a series of four consecutive signature traces derived from the section of the gnat's wing of Fig. 39A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention.

Fig. 40A is a graphical representation similar to that shown in Fig. 38A.

Fig. 40B is a series of consecutive signature traces at moderate density derived from the section of the gnat's wing of Fig. 40A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention.

Fig. 41A is a graphical representation similar to that shown in Fig. 38A.

Fig. 41B is a series of consecutive signature traces at higher density derived from the section of the gnat's wing of Fig. 41A utilizing an AC coupled and buffered HF signal from the optical drive according to the present invention.

Figs. 42A, 42B, and 42C are pictorial representations of the gnat's wing of Fig. 36 as rendered by methods according to the present invention respectively utilizing either an AC coupled and buffered HF signal, a DC coupled and buffered "A" signal, or a DC coupled and buffered HF signal from an optical drive assembly.

Fig. 43 is a graphical representation illustrating the relationship between Figs. 43A, 43B, and 43C.

Figs. 43A, 43B, and 43C are electrical schematics of a second embodiment of the amplifier stages that may be implemented according to the present invention in the buffer cards shown in Figs. 13 and 14.

Fig. 44 is a top view of a circuit board including a triggering detection assembly according to another aspect of the present invention. The circuit board includes an opening or pass-through port 401 which is needed when implemented in a top detector drive arrangement utilizing a transmissive disc such as those disclosed in commonly

assigned U.S. Patent No. 5,892,577 entitled "Apparatus and Method for Carrying Out Analysis of Samples" and U.S. Provisional Application No. 60/247,465 entitled "Disc Drive for Optical Bio-Disc". When employed with conventional drives using reflective discs and a typically positioned proximal or bottom detector, the pass-through port 401 is not required.

Fig. 45 is an electrical schematic of the triggering circuit shown in Fig. 44.

To acquire information concerning the investigational structures, the optical disc drive according to the present invention is provided with suitable triggering circuitry implemented to trigger when detection of the unprocessed RF signal is needed. This is necessary because the type of signal processing performed by DSP 32, which typically includes demodulation, decoding, and error checking, is intended to convert EFM-encoded information on the RF signal to a specific digital format. RF signals processed in this manner cannot be easily used to detect the dual peaks associated with investigational structures. Thus the signal or signals of interest are tapped-off before the drive DSP and the trigger board and trigger circuitry shown in Figs. 44 and 45 are implemented as discussed above.

The following discussion is directed to the DSP embodiment of the present invention. In accordance with other principles of the present invention, however, it is possible to programmably reconfigure chip set 30, Fig. 6, so that physical modification of the optical disc drive is not necessary. One way this may be accomplished is by programming DSP 32 to operate simply as an A/D converter rather than as, *inter alia*, a demodulator/decoder. In such a configuration, the DSP chip takes the place of the external A/D converter 150 and supplies the digitized HF signals directly to host data bus. Investigational structures may be detected by analyzing the resulting digitized HF signal. Alternatively, investigational structures could be detected by routing an unprocessed HF signal through the chip set to an output terminal of the disc drive, connecting the signal to a personal computer, and using hardware and/or software within the personal computer to perform the A/D conversion.

It is possible to programmably configure DSP 32 as an A/D converter in multiple ways. For example, a configuration routine stored in program memory 39 may operate via controller 38 to reconfigure DSP 32. Alternatively, an application program may be

able to selectively reconfigure DSP 32 through interface circuitry 36 as required. DSP 32 may also configure itself as an A/D converter when it receives a certain type of HF signal. These methods are merely illustrative, and any other suitable software or firmware based reconfiguration methods or path may be used if desired.

5 Fig. 46 is a functional block diagram of a digital signal processing circuit programmably configured as an analog to digital converter in accordance with the principles of an alternate embodiment of the present invention as represented in Fig. 8. Fig. 46 shows a block diagram illustrating some of the ways in which the processing resources within DSP 32 may be reconfigured to produce a suitable A/D converter
10 according to the present invention. In one possible arrangement, for example, A/D block 42 may be disconnected from path 45 and connected directly to output interface 48 through path 43. In this case, the digitized HF signals completely bypass blocks 44 and 46 and travel to output interface 48. In another arrangement, digitized signals from A/D block 42 travel on path 45, but pass through blocks 44 and 46 without being processed. In some embodiments, it may be desirable to turn OFF blocks 44 and 46 or place them in a low power operating mode to reduce power consumption (e.g., in battery operated disc drives). Although the foregoing illustrates several possible A/D converter arrangements, any other suitable arrangement of resources within DSP 32 may be used if desired.

15
20 Fig. 47 is a flow chart illustrating some of the steps involved in detecting investigational elements in accordance with the DSP embodiment of the present invention illustrated in Fig. 46. As shown in Fig. 47, when it is desired to enter detection mode (step 100), a portion of a signal processing system within the drive is configured to operate as an analog to digital converter (step 101). This may include programmably
25 reconfiguring one or more chips in chip set 30 (e.g., DSP 32) by employing a remote application program or by using a routine stored in a local program memory 39. This conversion eliminates the need to physically modify the disc drive electronics and to take advantage of the processing resources within the chip set.

30 At step 102, a plurality of analog data signals are acquired from disc 11, which preferably includes investigational structures 136 (Fig. 9), using objective assembly 10 (Fig. 1). Next, the analog data signals are combined to produce a sum (HF) signal and

a tracking error (TE) signal (step 103). Both signals are provided to the signal processing system at step 104. At step 105, the basic information required to operate the disc drive such as tracking, focus, and speed control is extracted from the tracking error signal. Simultaneously, the signal processing system may convert the sum signal into a digital signal which is provided to output interface 36 at step 105. The digitized sum signal is subsequently used to characterize the investigational structures present on disc 11. Once the scanning process is complete, the disc drive may be directed to exit the detection mode (step 106). At this point, the portion of the chip set (e.g., DSP 32) previously configured as an A/D converter may be returned to its original configuration and normal CD, CD-R, or DVD operation may resume (step 107).

While this invention has been described in detail with reference to certain preferred embodiments, it should be appreciated that the present invention is not limited to those precise embodiments. Rather, in view of the present disclosure which describes the current best mode for practicing the invention, many modifications and variations would present themselves to those of skill in the art without departing from the scope and spirit of this invention. The scope of the invention is, therefore, indicated by the following claims rather than by the foregoing description. All changes, modifications, and variations coming within the meaning and range of equivalency of the claims are to be considered within their scope.

What Is Claimed Is:

1 1. An optical disc system for detecting investigational features on an optical disc
2 assembly, said system comprising:
3 a photodetector circuit implemented to generate at least one information-carrying
4 signal from the optical disc assembly; and
5 a signal processing system coupled to said photodetector circuit that receives
6 said at least one information-carrying signal and obtains therefrom operational
7 information used to operate the optical disc system, and data indicative of the presence
8 of any respective investigational feature associated with the optical disc assembly.

1 2. The optical disc system according to claim 1 wherein said information-carrying
2 signal is an analog data signal.

3 3. The optical disc system according to either claim 1 or 2 wherein said data is a
4 set of digital data.

5 4. The optical disc system according to claim 3 wherein said set of digital data is
6 representative of said at least one information-carrying signal.

7 5. The optical disc system according to claim 2 wherein said data is
8 representative of said analog data signal.

1 6. A method of obtaining information from an optical disc drive about an investi-
2 gational feature associated with a test sample in an optical disc assembly, said method
3 comprising the steps of:
4 depositing a test sample relative to a respective optical disc assembly;
5 loading said respective optical disc assembly into an optical disc drive;
6 directing an incident beam onto the optical disc assembly;
7 allowing said incident beam to interact with said test sample;
8 detecting a return beam formed as a result of said incident beam interacting with
9 said test sample; and

10 processing said return beam to acquire information about an investigational
11 feature associated with said test sample.

1 7. A method of obtaining information from an optical disc drive about an
2 investigational feature associated with a test sample in an optical disc assembly, said
3 method comprising the steps of:
4 depositing a test sample relative to a respective optical disc assembly;
5 loading said respective optical disc assembly into an optical disc drive;
6 directing an incident beam onto the optical disc assembly;
7 allowing said incident beam to interact with said test sample;
8 detecting a return beam formed as a result of said incident beam interacting with
9 said test sample to form a plurality of analog data signals;
10 configuring a portion of a signal processing system in the optical disc drive as an
11 analog to digital converter;
12 summing said plurality of analog data signals to produce a sum signal;
13 combining said plurality of analog data signals to produce a tracking error signal;
14 providing said sum signal and said tracking error signal to said signal processing
15 system;
16 obtaining from said tracking error signal information used to operate the optical
17 disc system; and
18 converting said analog sum signal to a digital signal using said portion of said
19 signal processing circuit.

1 8. A method of obtaining information from an optical disc drive about an investi-
2 gational feature associated with an optical disc assembly, said method comprising the
3 steps of:
4 configuring a portion of a signal processing system in the optical disc drive as an
5 analog to digital converter;
6 acquiring a plurality of analog data signals from an optical disc assembly using a
7 plurality of photodetector circuits;
8 summing said plurality of analog data signals to produce a sum signal;

9 combining said plurality of analog data signals to produce a tracking error signal;
10 providing said sum signal and said tracking error signal to said signal processing
11 system;
12 obtaining from said tracking error signal information used to operate the optical
13 disc system; and
14 converting said analog sum signal to a digital signal using said portion of said
15 signal processing circuit.

1 9. The method of claim 8 wherein said acquiring further comprises receiving
2 signals indicative of said investigational structures located on said surface of said
3 optical disc assembly in said sum signal.

1 10. The method of claim 8 wherein said configuring further comprises adapting a
2 portion of an optical disc drive chip set to operate as an analog to digital converter.

1 11. The method of claim 8 further comprising characterizing said investigational
2 features based on said digital signal.

1 12. The method of claim 8 wherein said configuring further comprises
2 programming a digital signal processing chip within said signal processing system as an
3 analog to digital converter in order to convert said sum signals to digital signals.

1 13. The method of claim 8 wherein said signal processing system includes a
2 normalization block, an analog to digital converter block, a demodulation/decode block,
3 and an output interface block.

1 14. The method of claim 13 wherein said configuring further comprising creating
2 a path from said analog to digital converter block to said output interface block such that
3 said sum signal bypasses said demodulation/decode block.

1 15. The method of claim 8 wherein said signal processing system includes a
2 normalization block, an analog to digital converter block, a demodulation/decode block,

3 and an output interface block, said configuring further comprising creating a path from
4 said analog to digital converter block to said output interface block such that said sum
5 signal is unprocessed by said demodulation/decode block.

1 16. The method of claim 14 or 15 wherein said configuring further comprises
2 deactivating said demodulation/decode block.

1 17. A method for detecting investigational features on an optical disc assembly
2 using a standard optical disc drive, the method comprising:

3 adapting a portion of a signal processing system to operate as an analog to
4 digital converter;

5 acquiring a plurality of analog data signals from the optical disc assembly that
6 includes signals indicative of investigational features on the optical disc;

7 converting said analog data signals to digital data signals with said signal
8 processing system; and

9 characterizing said investigational features based on said digital signal.

1 18. The method of claim 17 wherein said adapting further comprises
2 programming a digital signal processing chip within said system as an analog to digital
3 converter.

4 19. A method for generating at least one digital signal from an optical disc drive,
5 said drive comprising: (a) at least one photodetector element for detecting light returned
6 from a surface of an optical disc assembly and for generating at least one analog signal,
7 said analog signal being substantially proportional to an intensity of said return light, and
8 (b) signal processing circuitry having at least one input and at least one output; said
9 method comprising:

10 receiving said at least one analog signal at said at least one input;

1 converting said at least one analog signal to said at least one digital signal, said
2 at least one digital signal being substantially proportional to said intensity; and

3 providing said at least one digital signal to said at least one output.

1 20. The method of claim 19 wherein said signal processing circuitry does not
2 demodulate said digital signal.

1 21. The method of claim 19 wherein said chip does not decode said digital
2 signal.

1 22. The method of claim 19 wherein said chip does not check for errors in said
2 digital signal.

1 23. The method of claim 19 wherein said chip does not demodulate, decode, nor
2 error check said digital signal.

1 24. The method of claim 19 further comprising combining two or more of said at
2 least one analog signal before said converting.

1 25. The method of claim 24 wherein said combining is selected from the group
2 consisting of adding, subtracting, dividing, multiplying, and any combination thereof.

1 26. The method of claim 25 wherein said combining is performed before said
2 converting.

1 27. The method of claim 25 wherein said combining is performed after said
2 converting.

1 28. The method of claim 19 further comprising supplying said at least one digital
2 signal to said output, after said converting, without substantially modifying said digital
3 signal between said converting and said providing.

1 29. The method of claim 28 wherein said signal processing circuitry comprises a
2 digital signal processor.

1 30. The method of claim 29 wherein said signal processing circuitry consists of a
2 digital signal processor.

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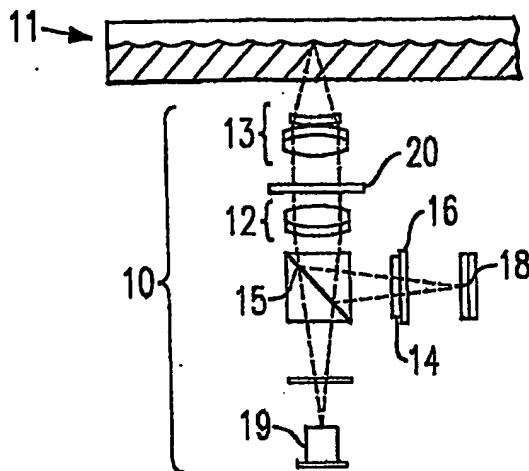


FIG. 1
Prior Art

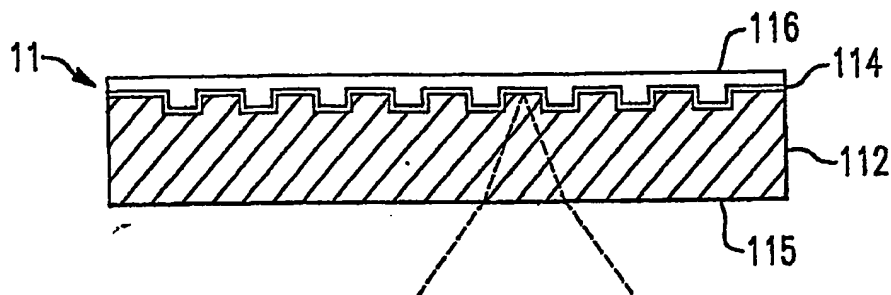


FIG. 2
Prior Art

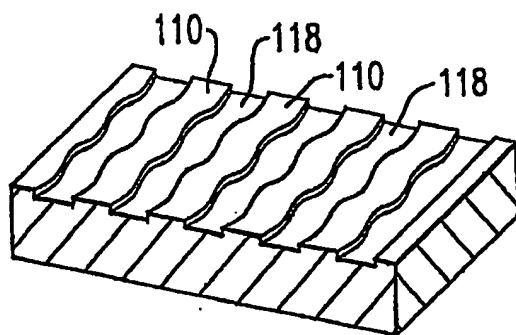
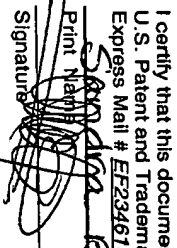


FIG. 3
Prior Art

60292103-051301

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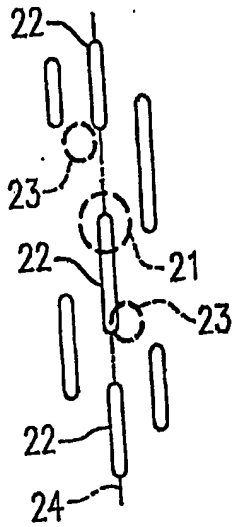


FIG. 5
Prior Art

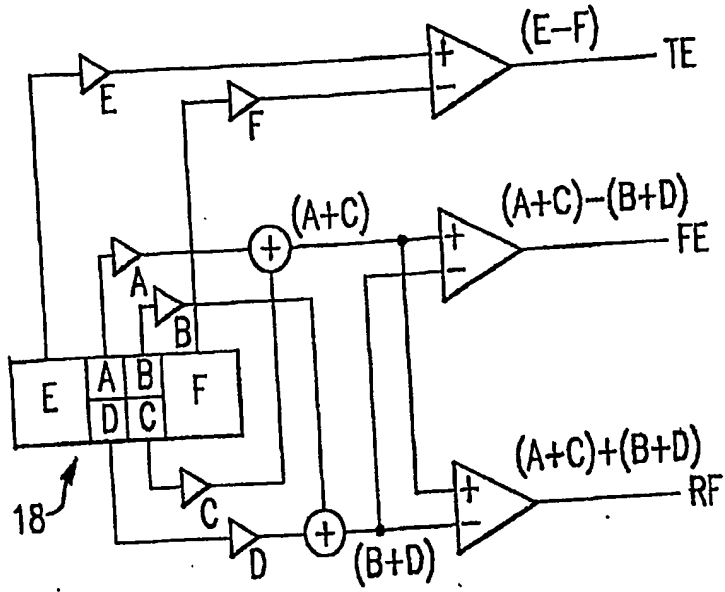


FIG. 4
Prior Art

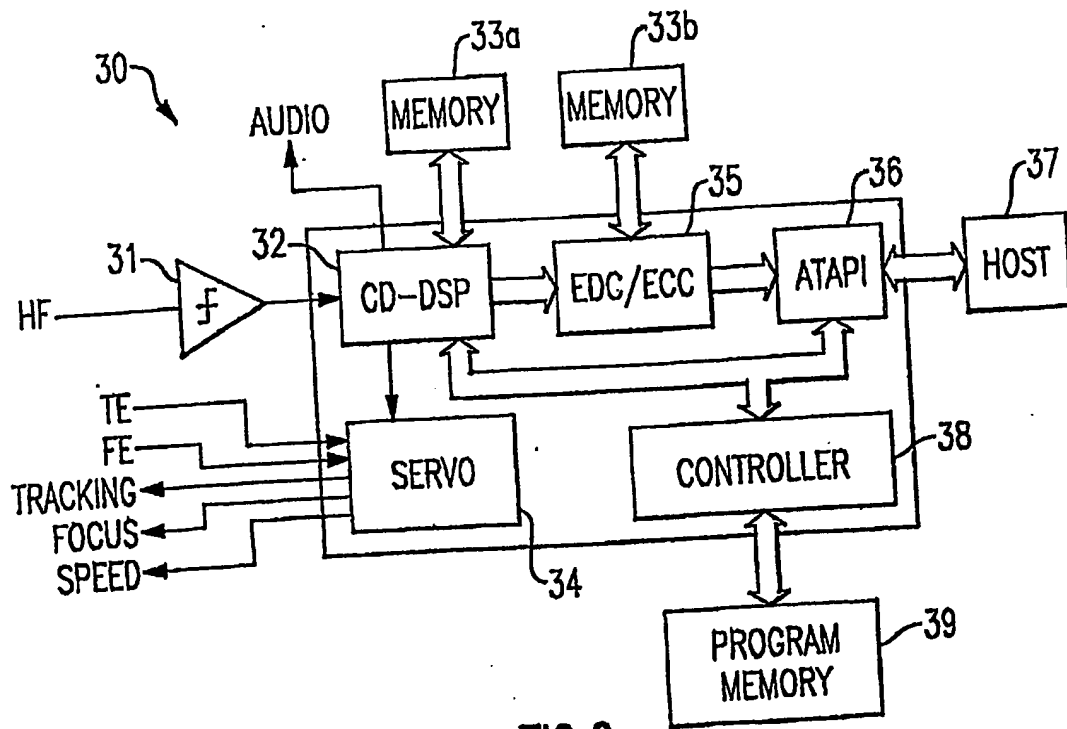


FIG. 6
Prior Art

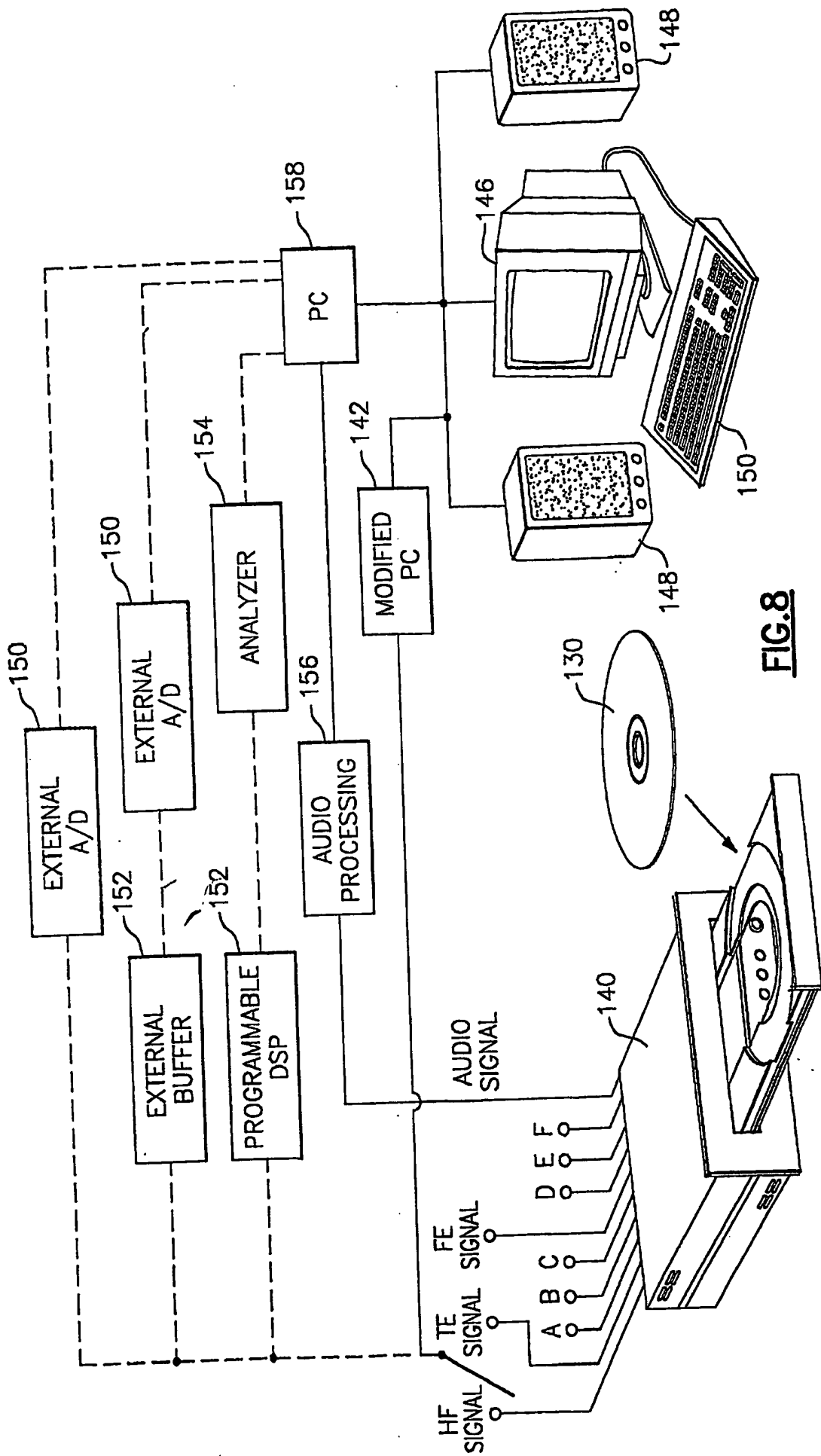


FIG. 8

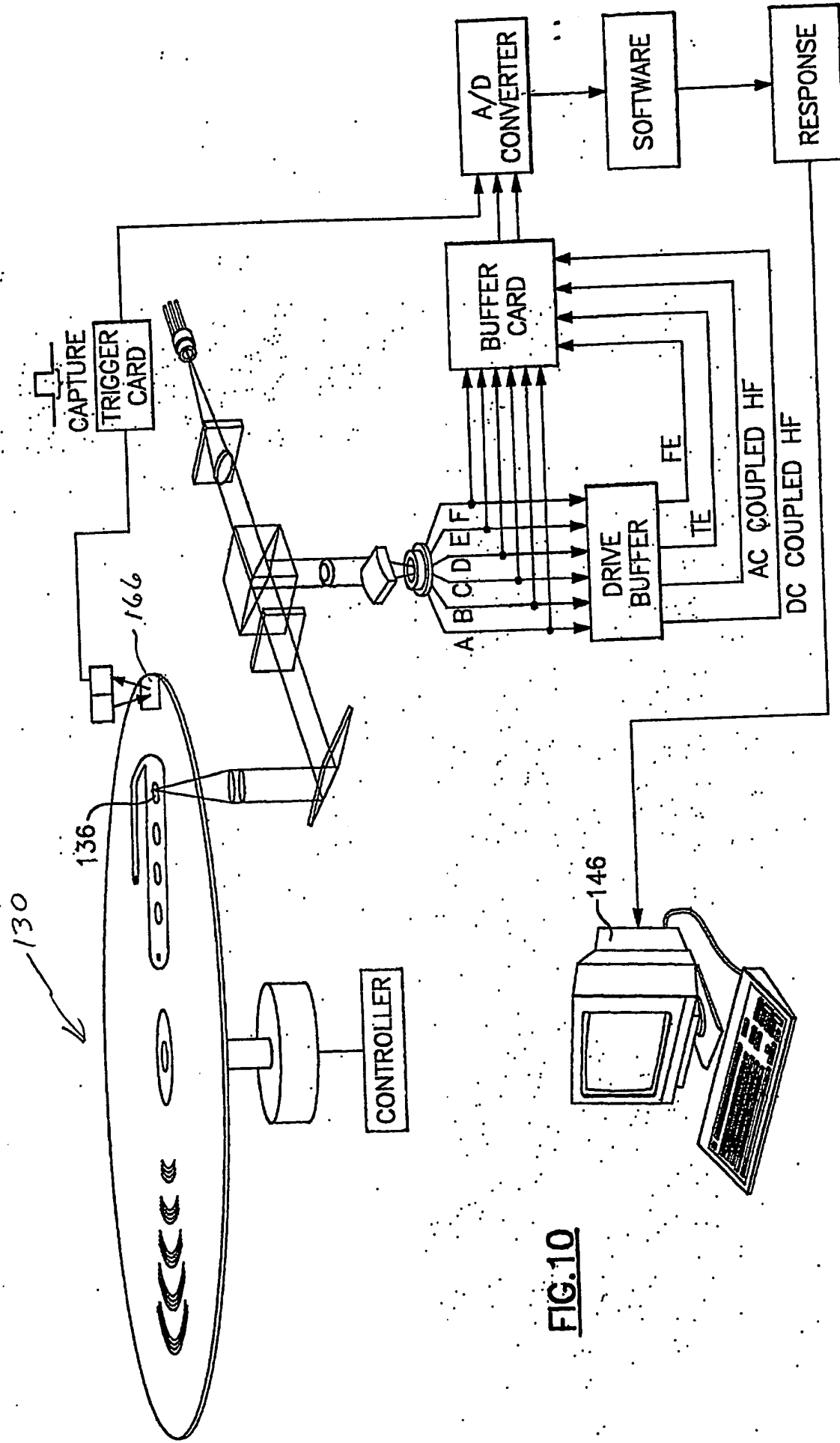


FIG. 10

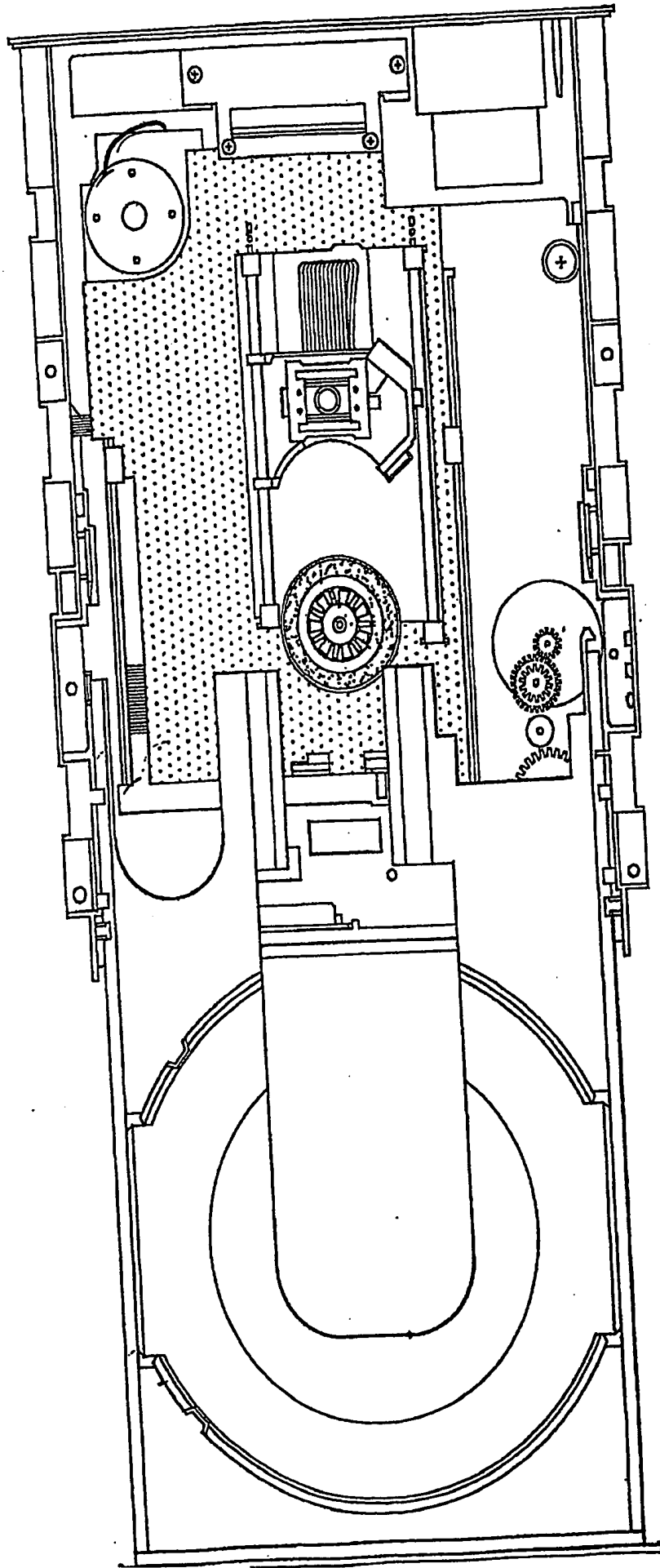


FIG. 11

FIG. 12

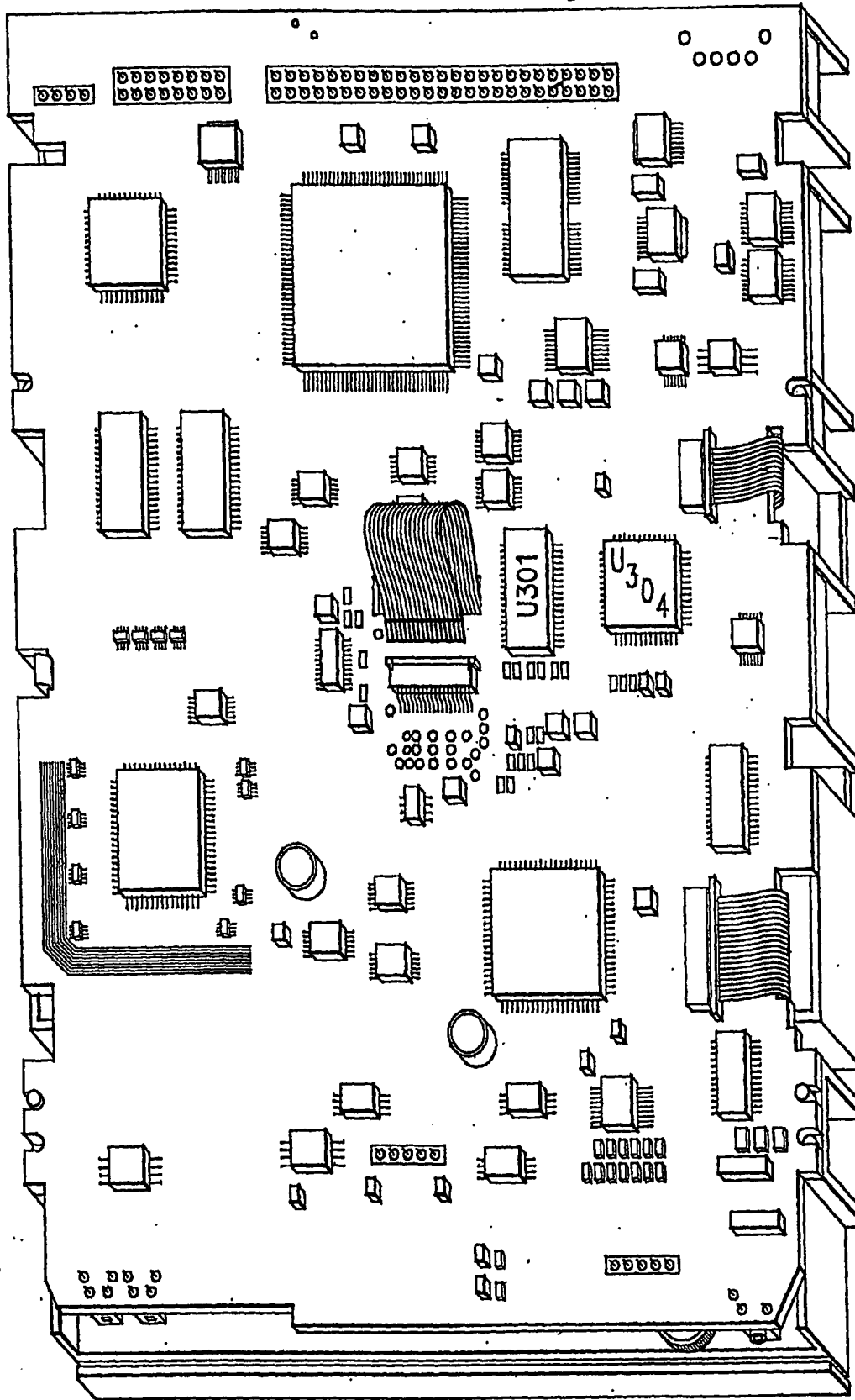


FIG.12

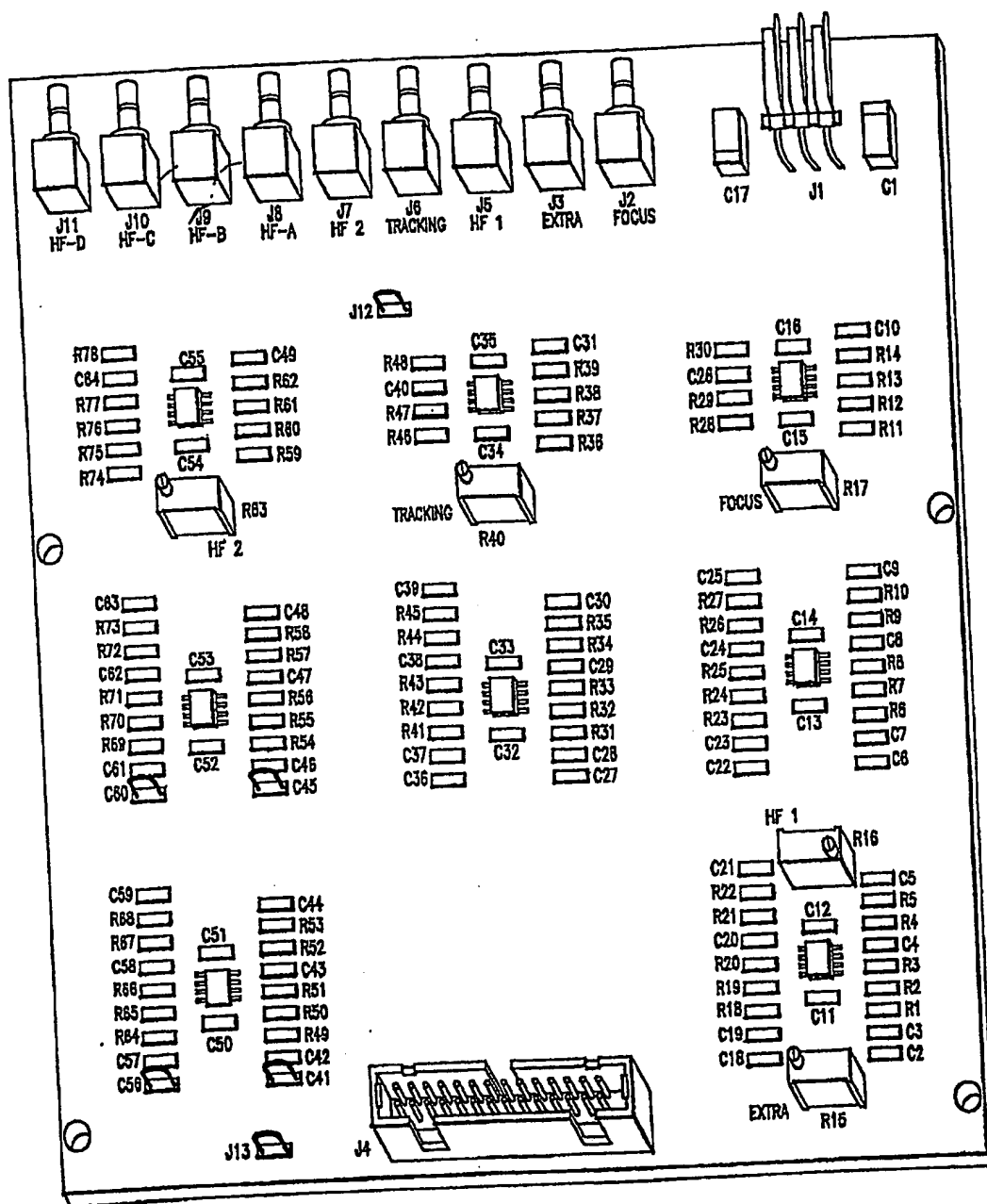


FIG.13

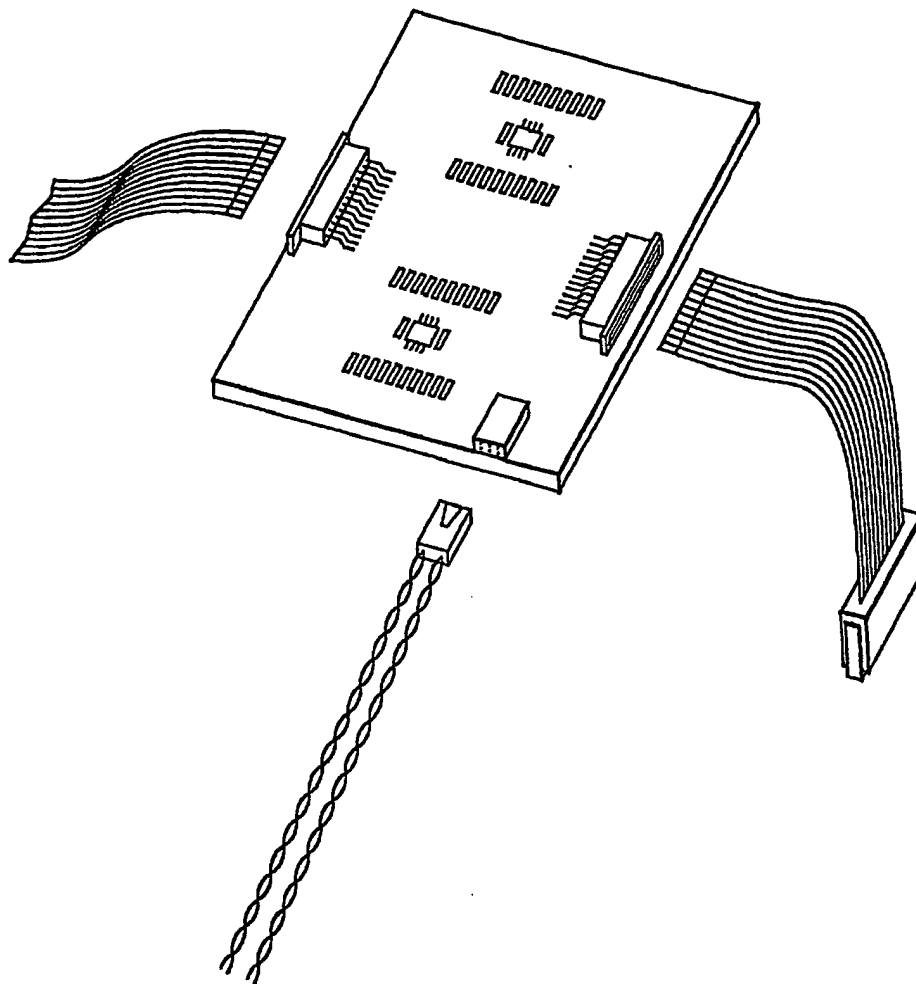


FIG.14

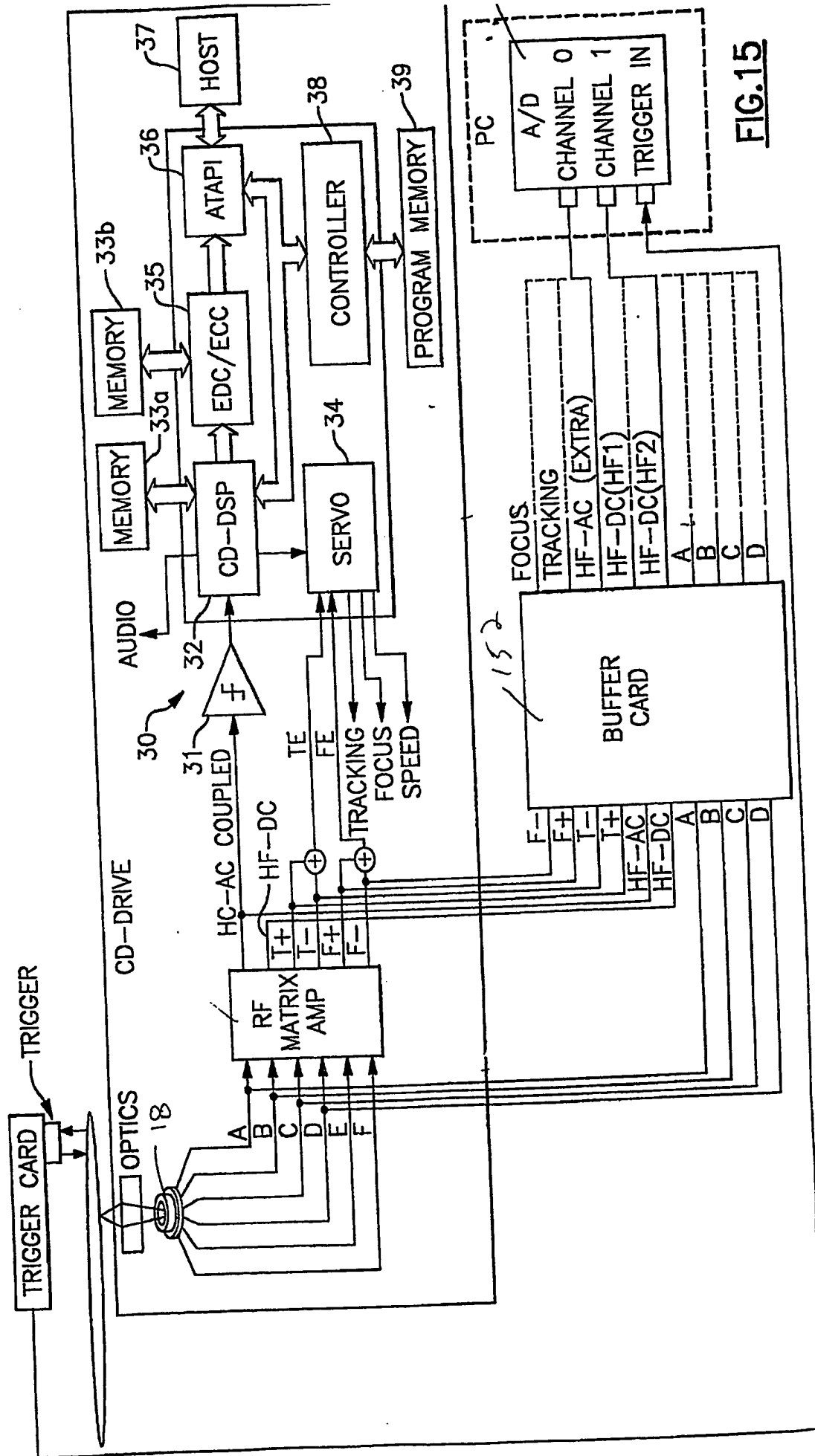


FIG.15

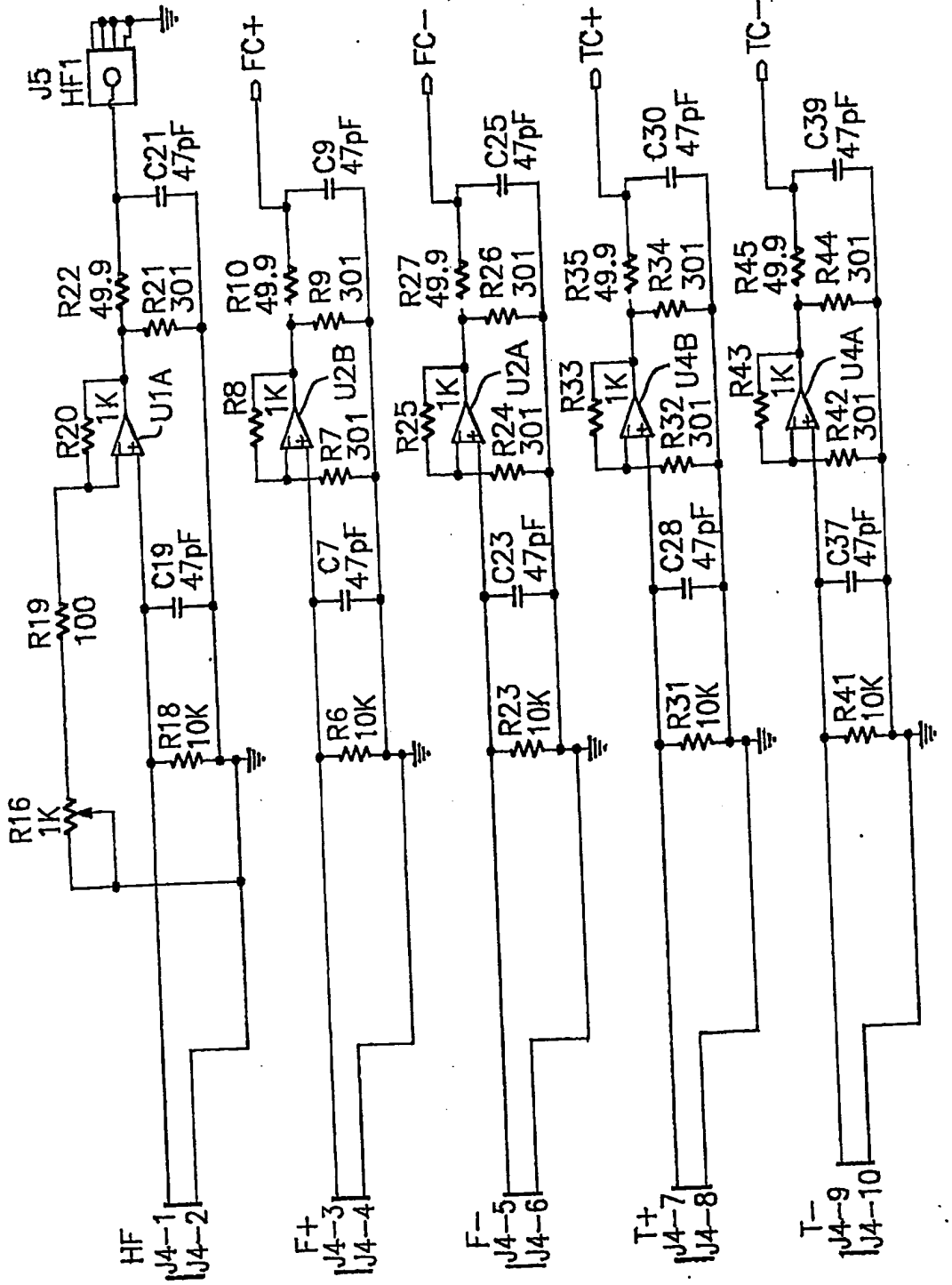


FIG. 16A

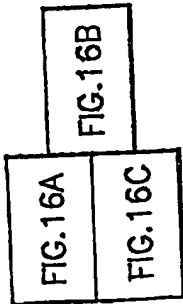


FIG. 16

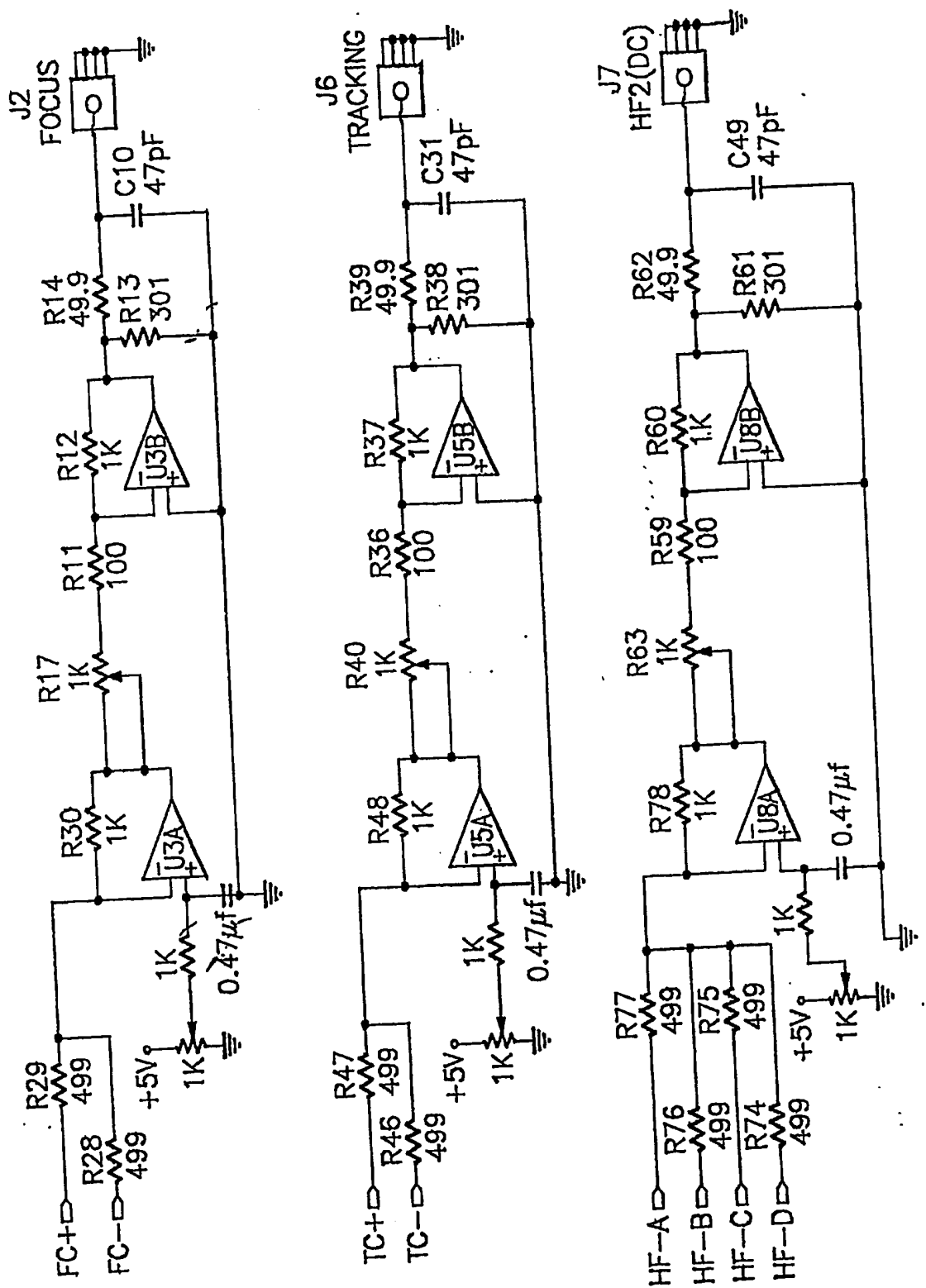


FIG. 16B

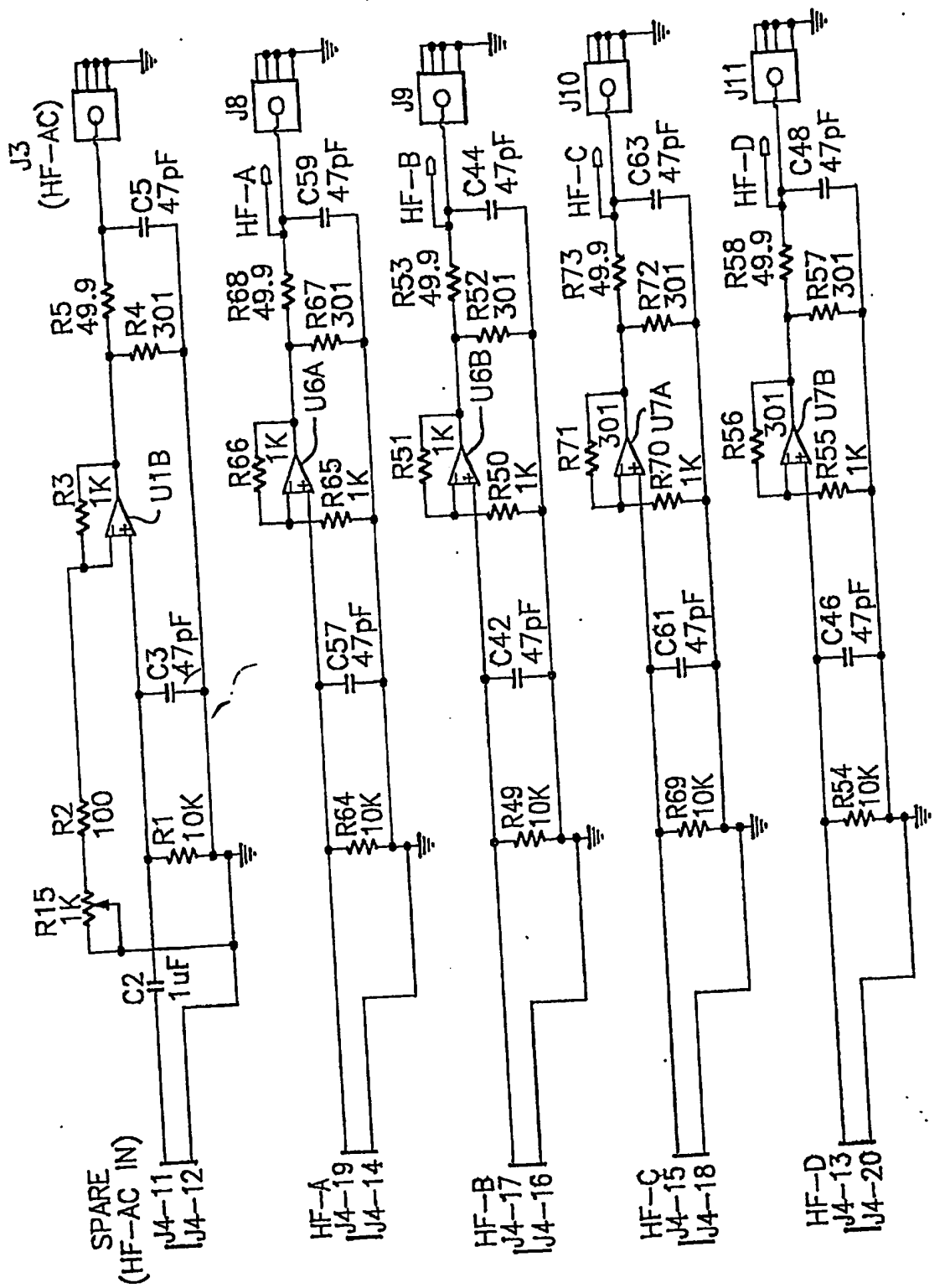


FIG. 16C

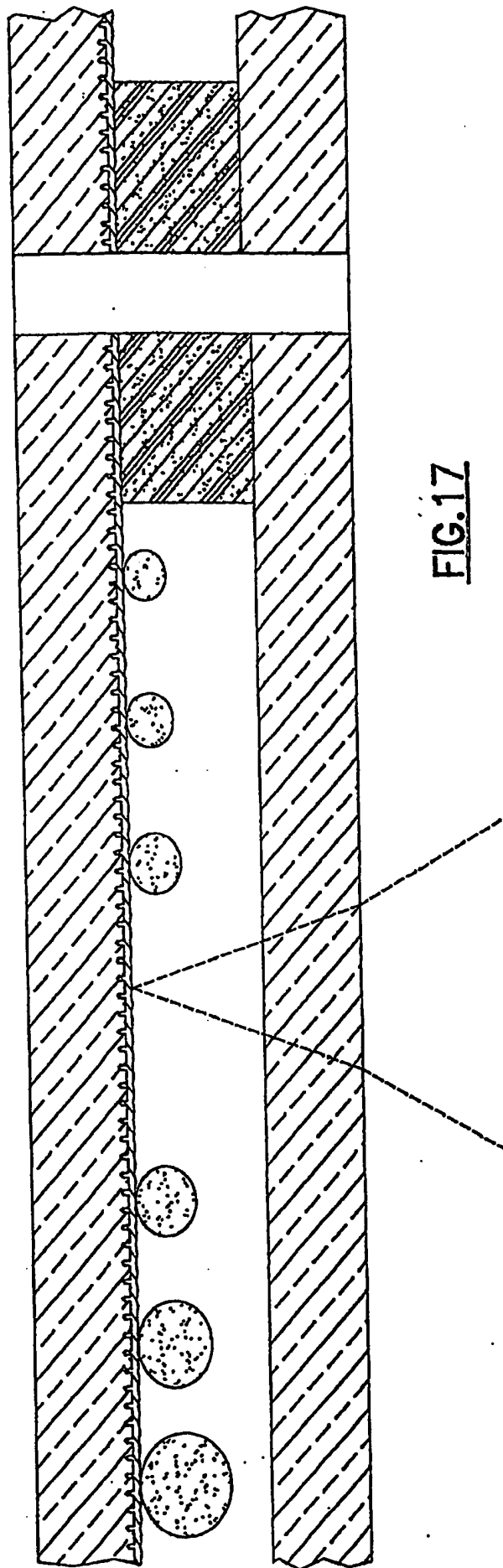


FIG. 17

FIG.18A

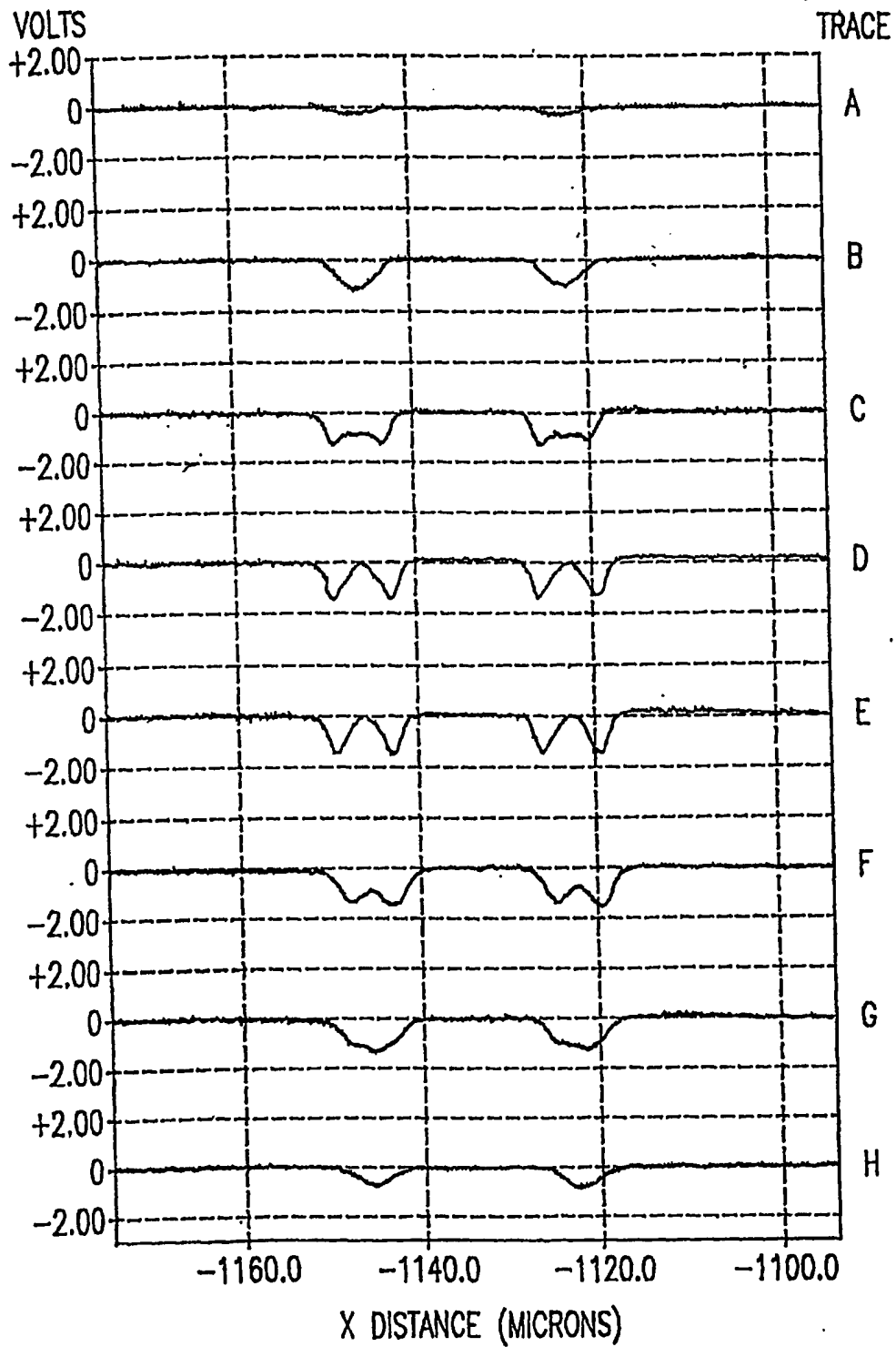
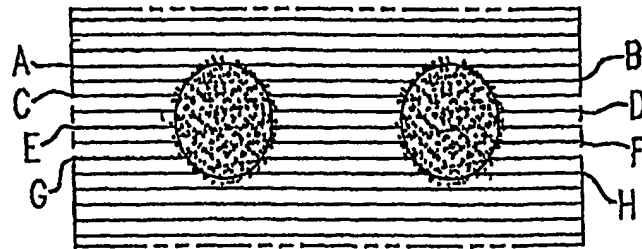


FIG.18B

FIG.19A

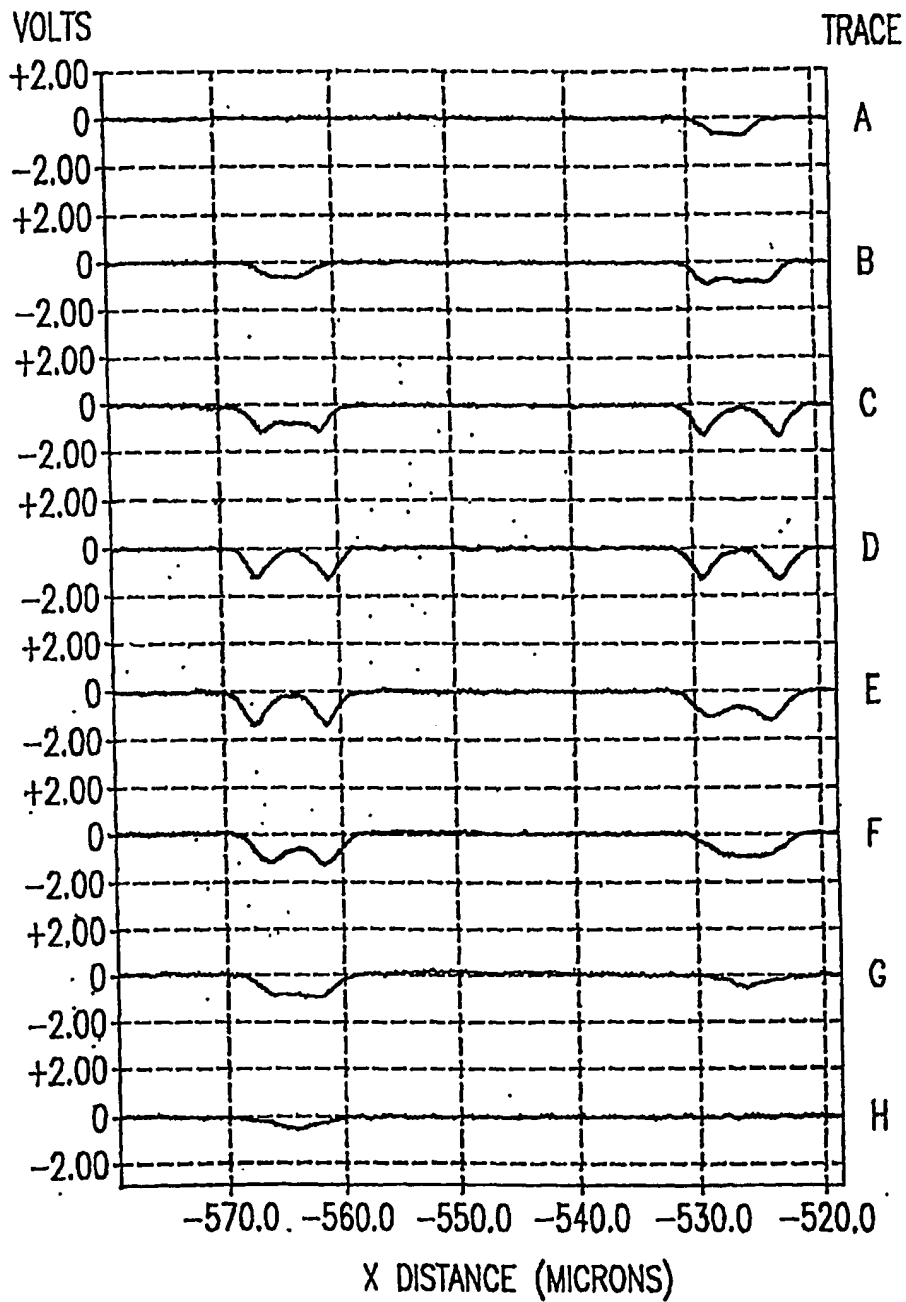
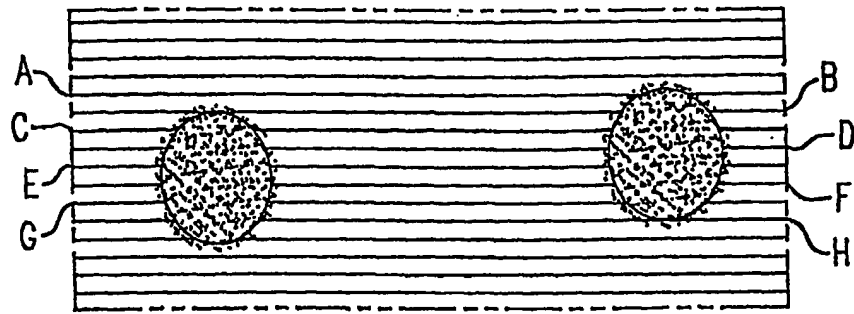


FIG.19B

FIG.20A

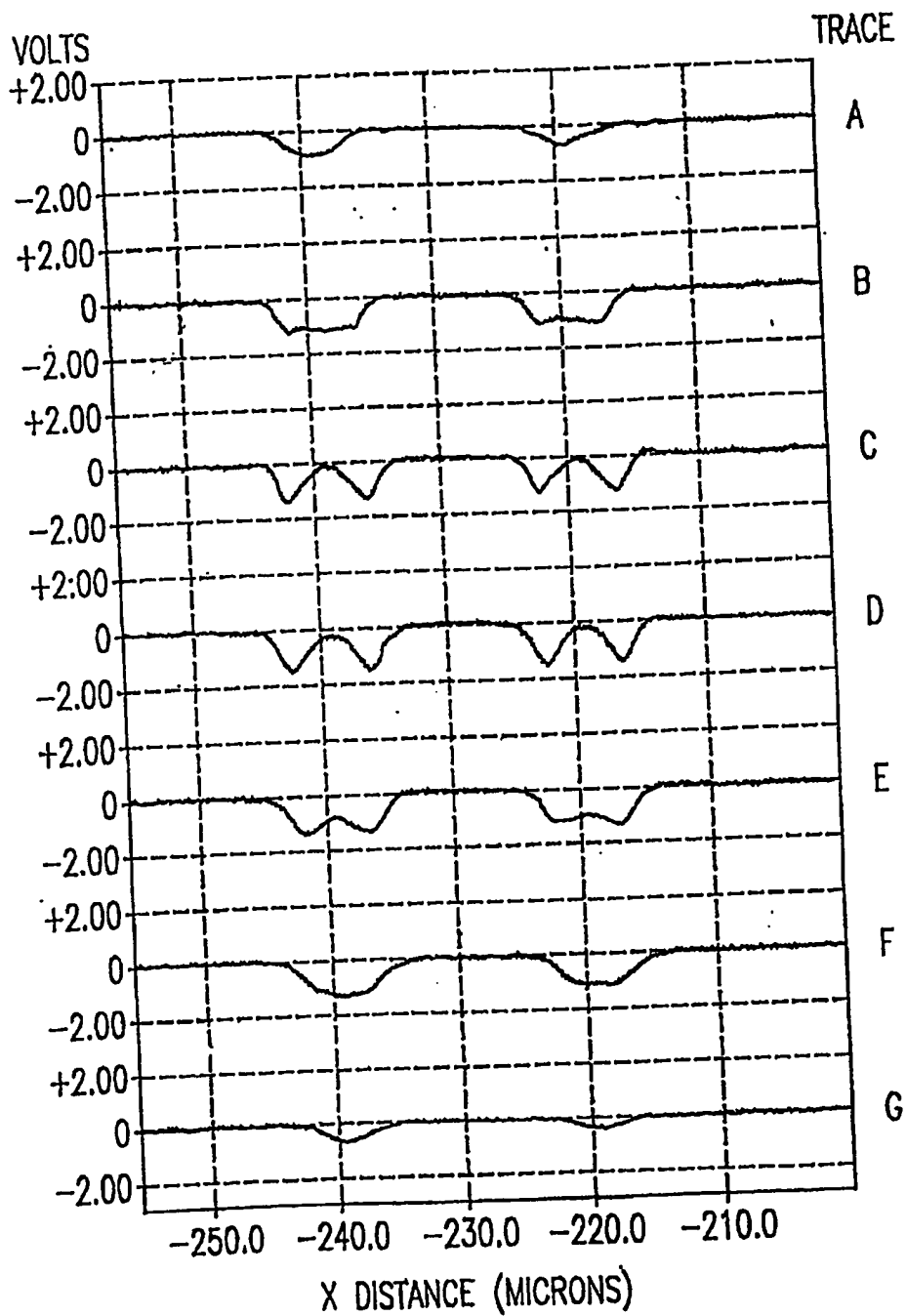
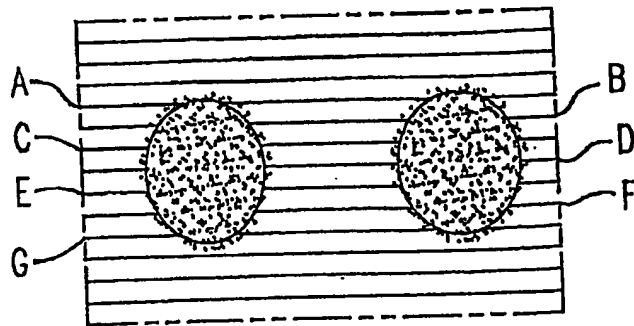


FIG.20B

FIG.21A

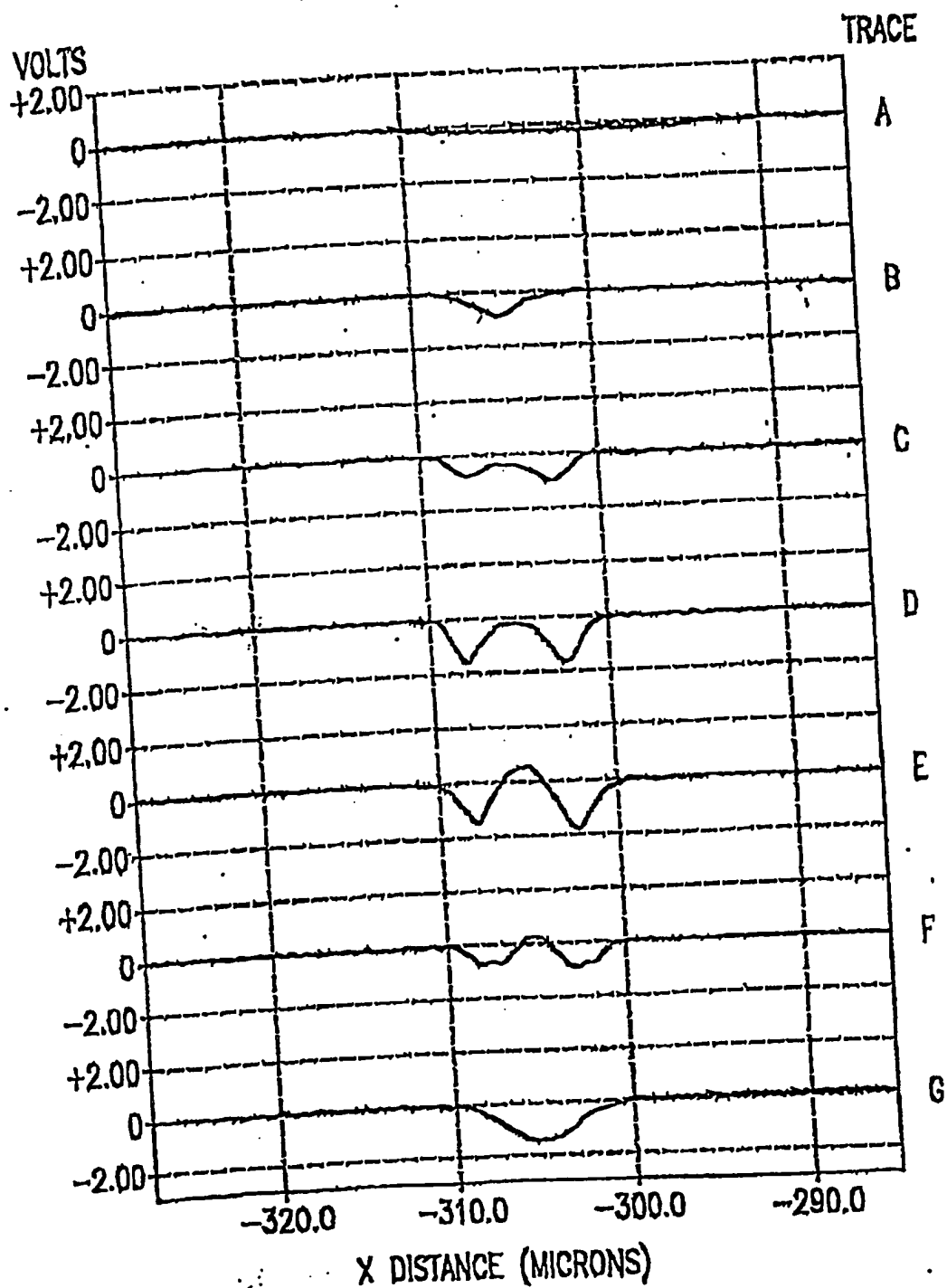
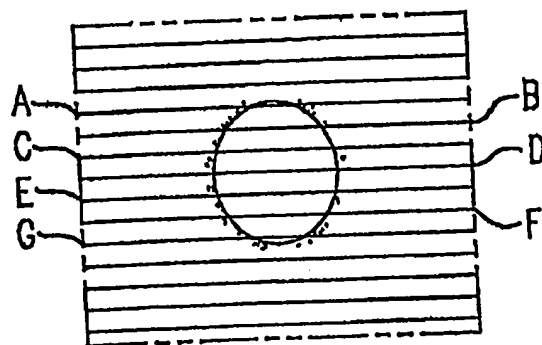


FIG.22A

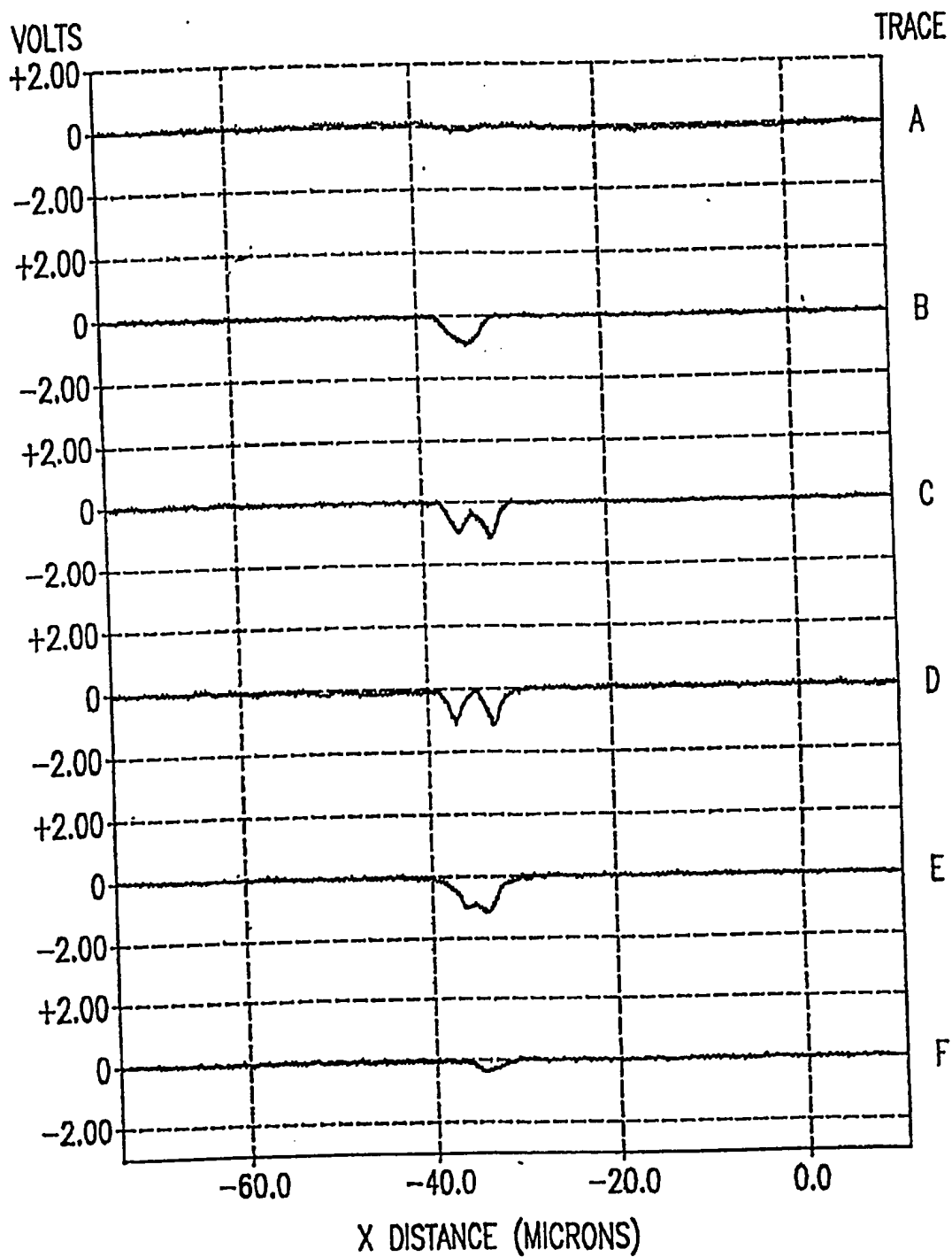
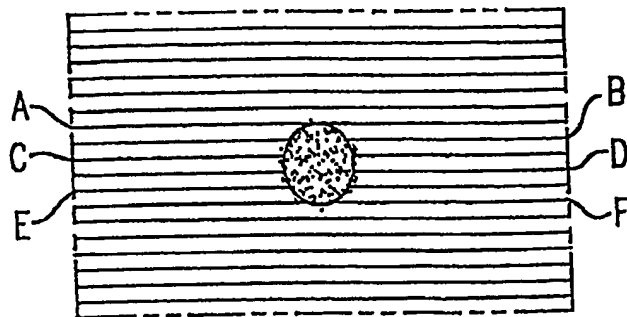


FIG.22B

FIG.23A

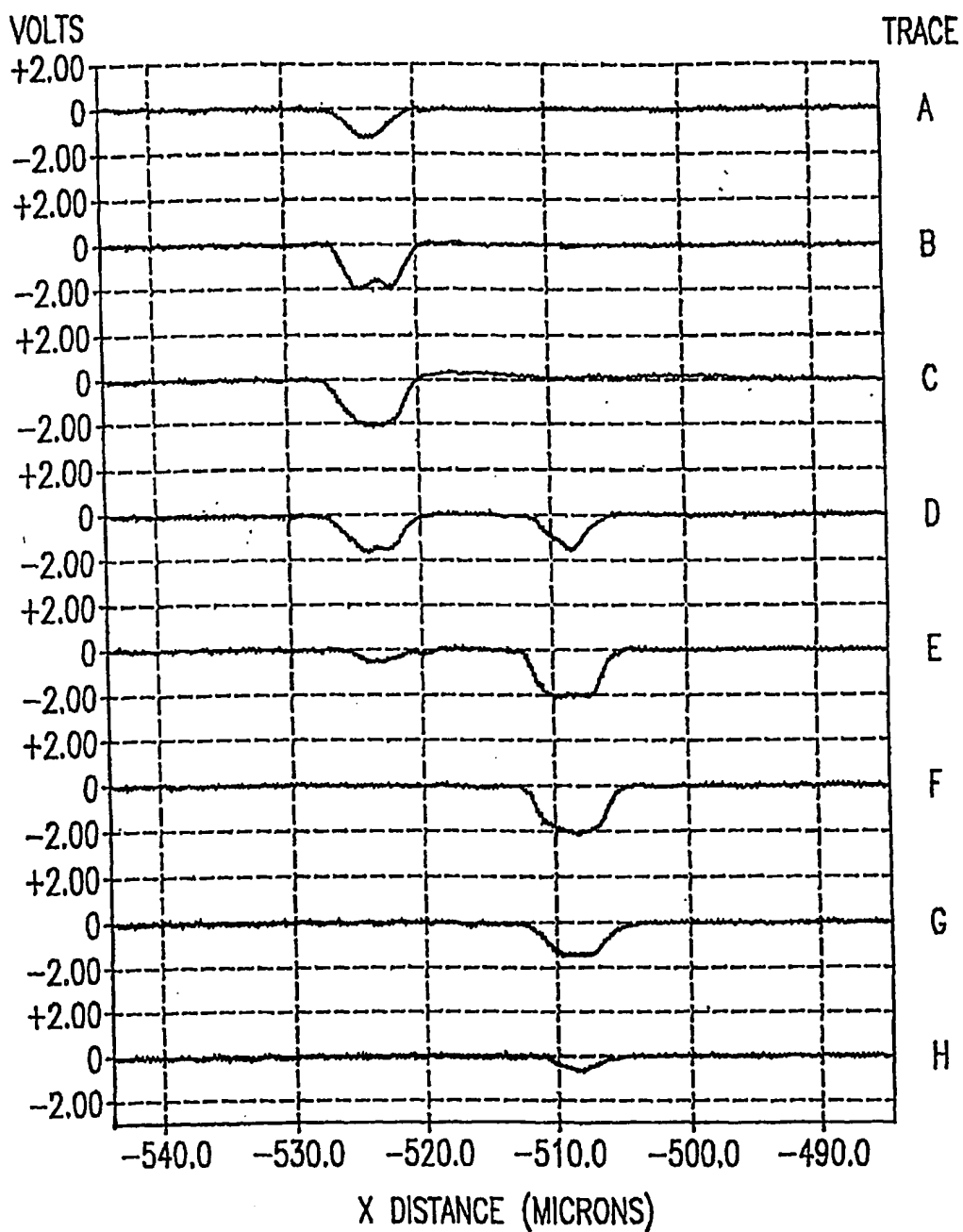
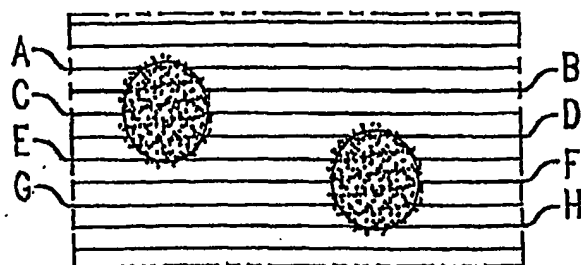


FIG.23B

FIG.24A

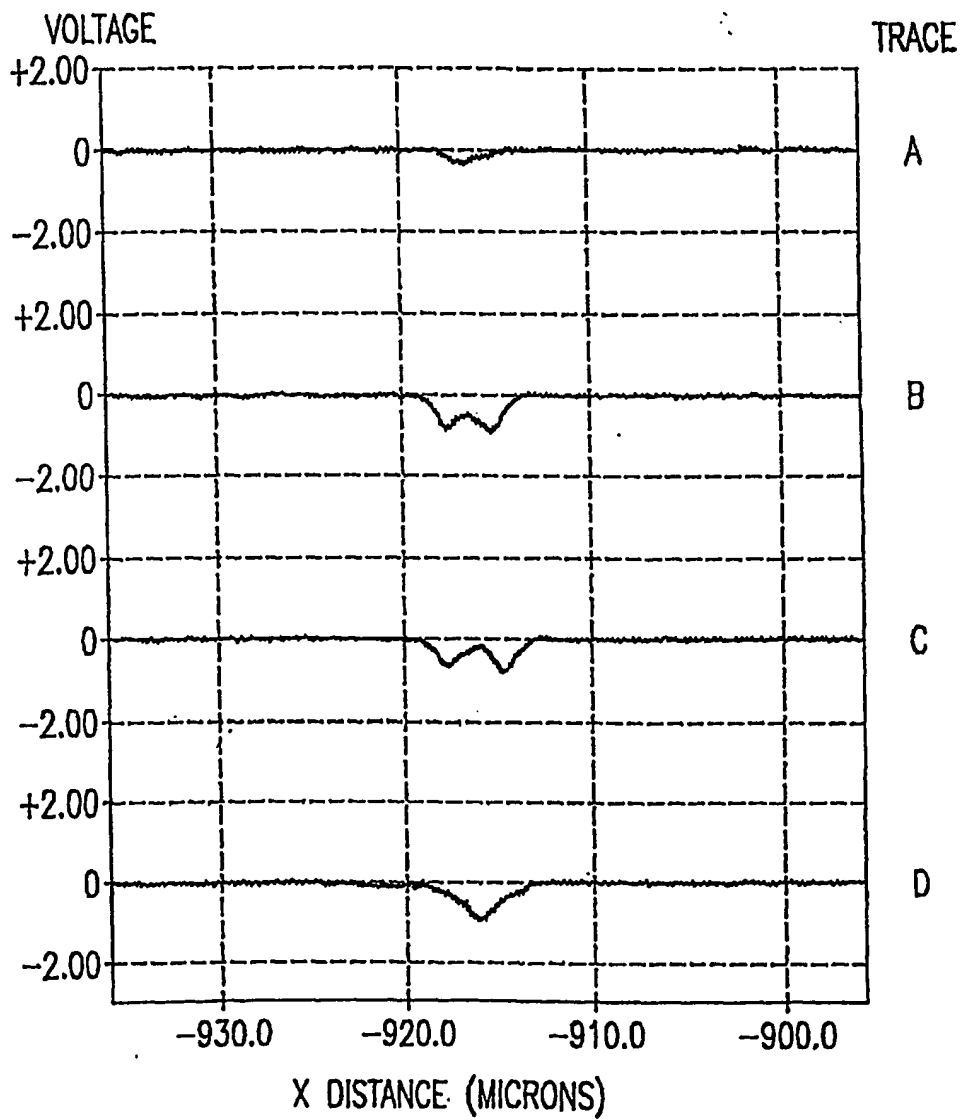
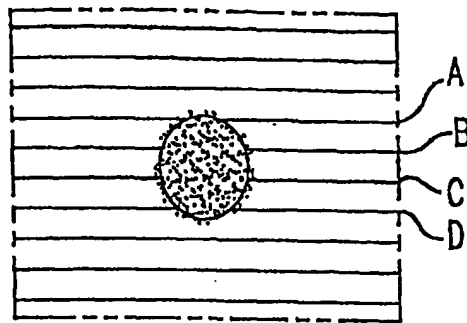


FIG.24B

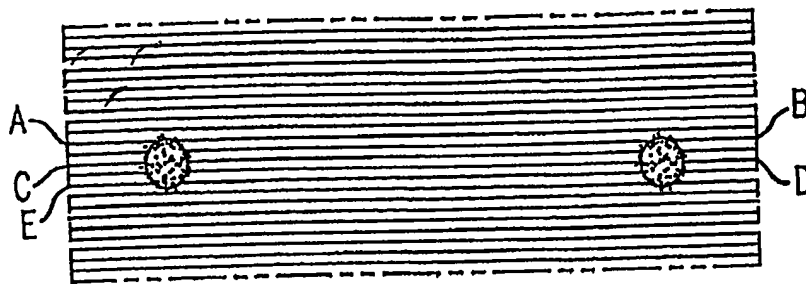


FIG.25A

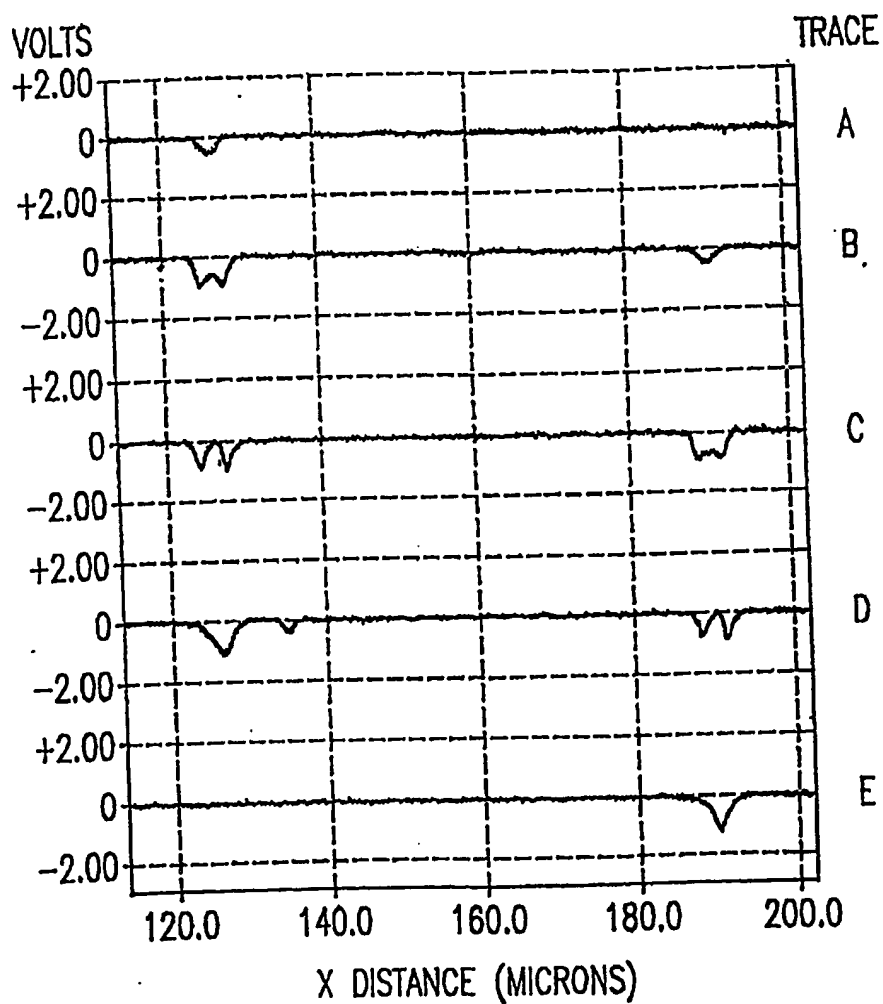


FIG.25B

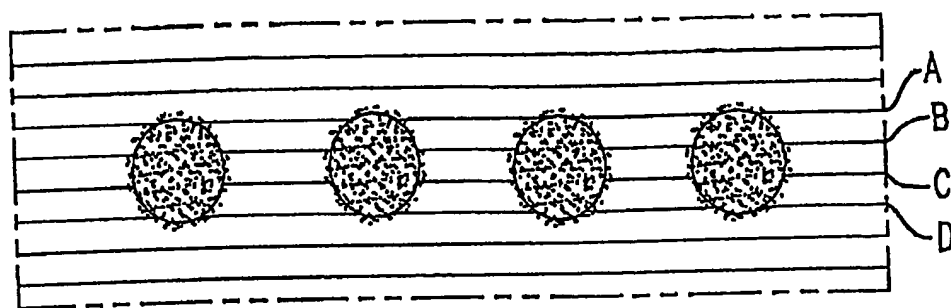


FIG.26A

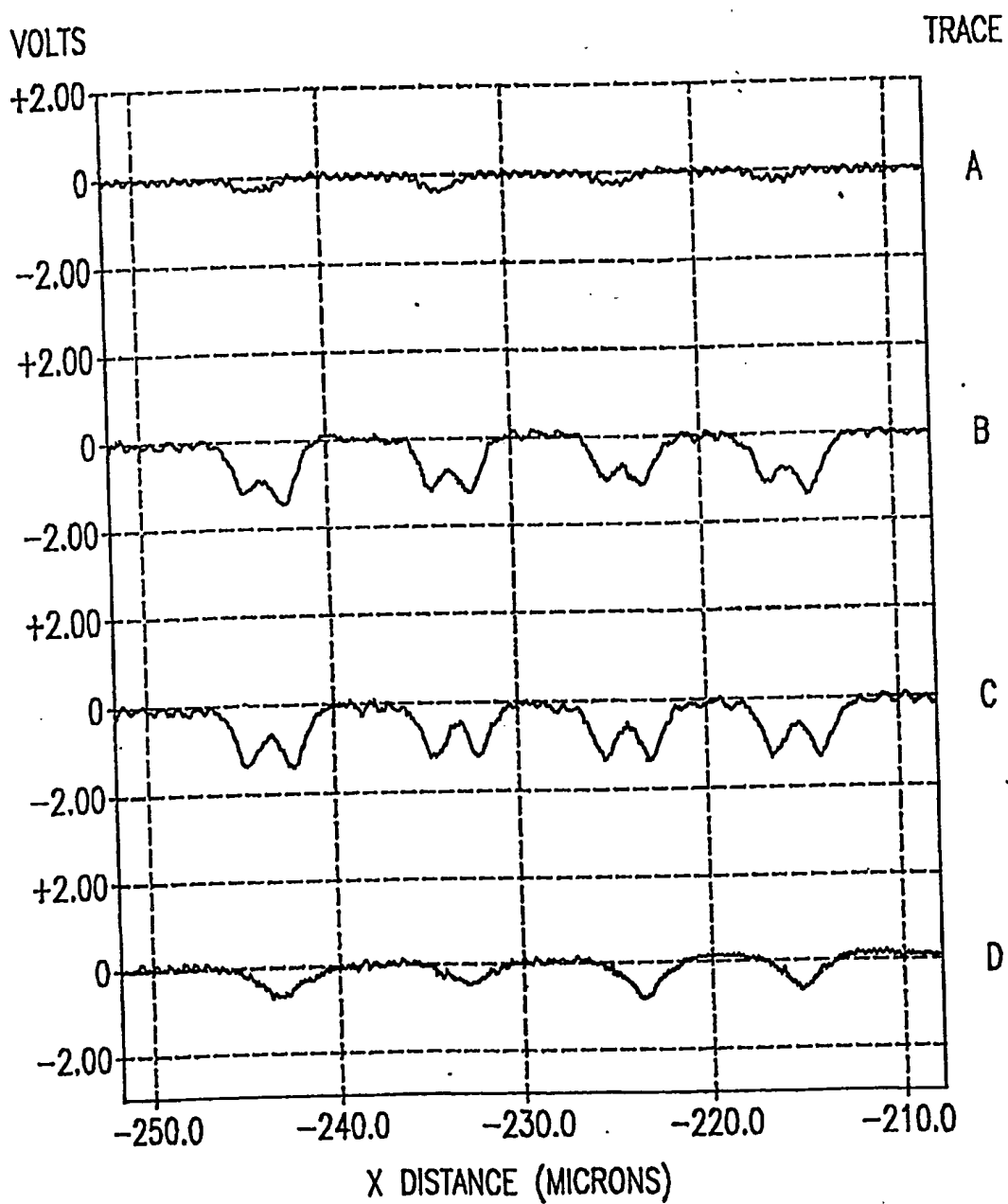


FIG.26B

FIG. 26A and FIG. 26B

FIG. 27A

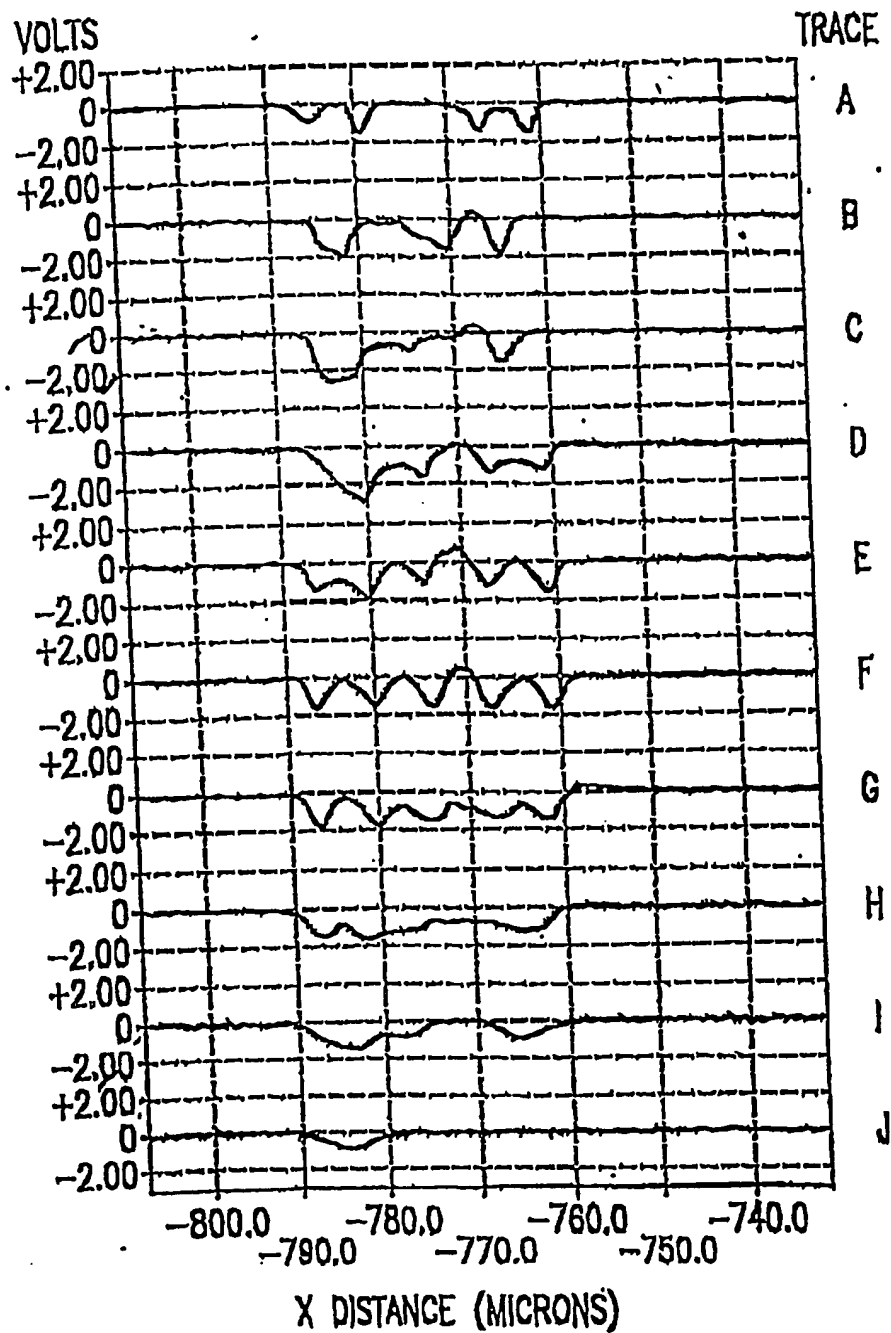
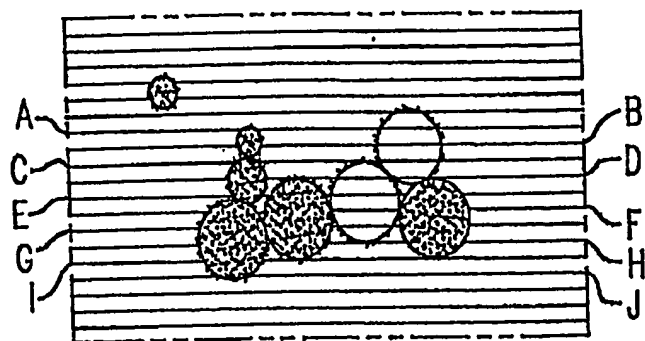


FIG. 27B

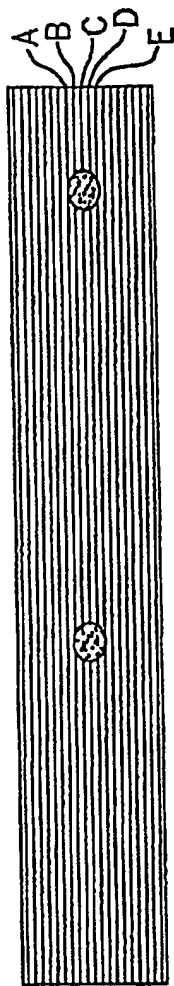


FIG.28A

TRACE

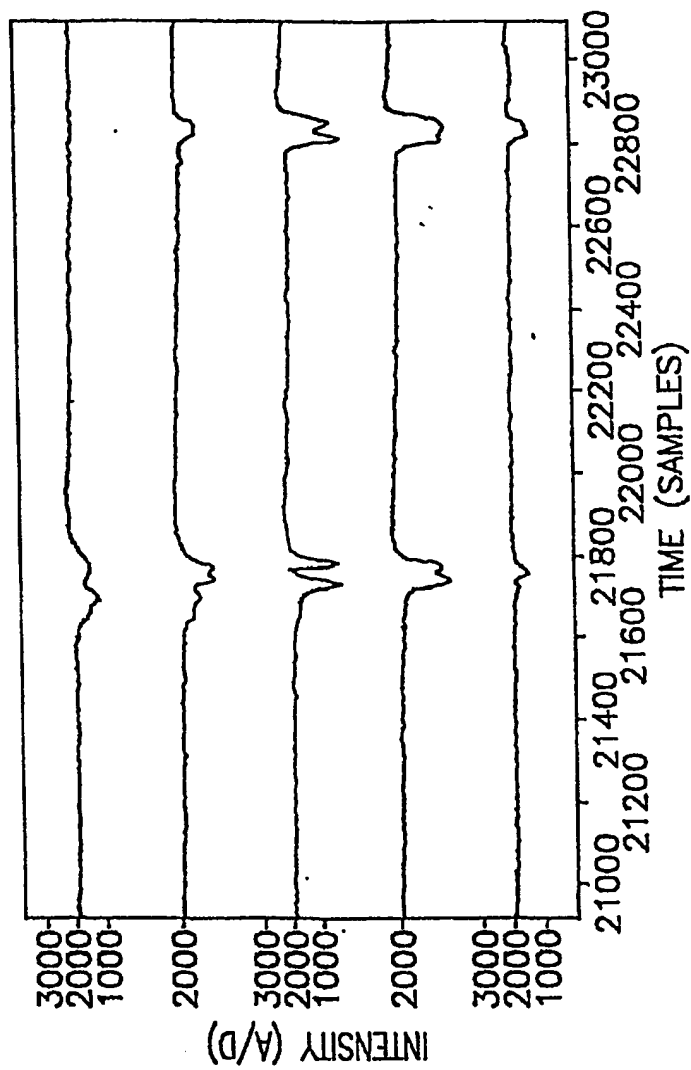


FIG.28B

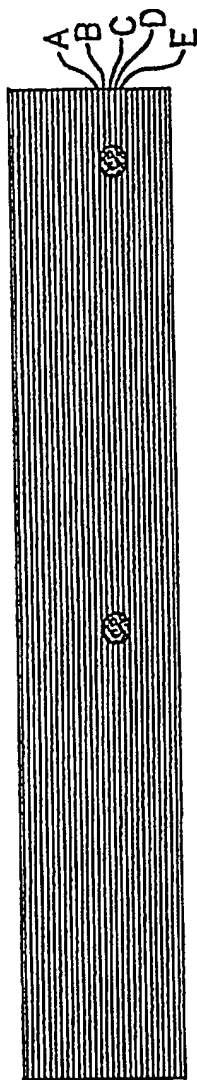


FIG. 29A

TRACE

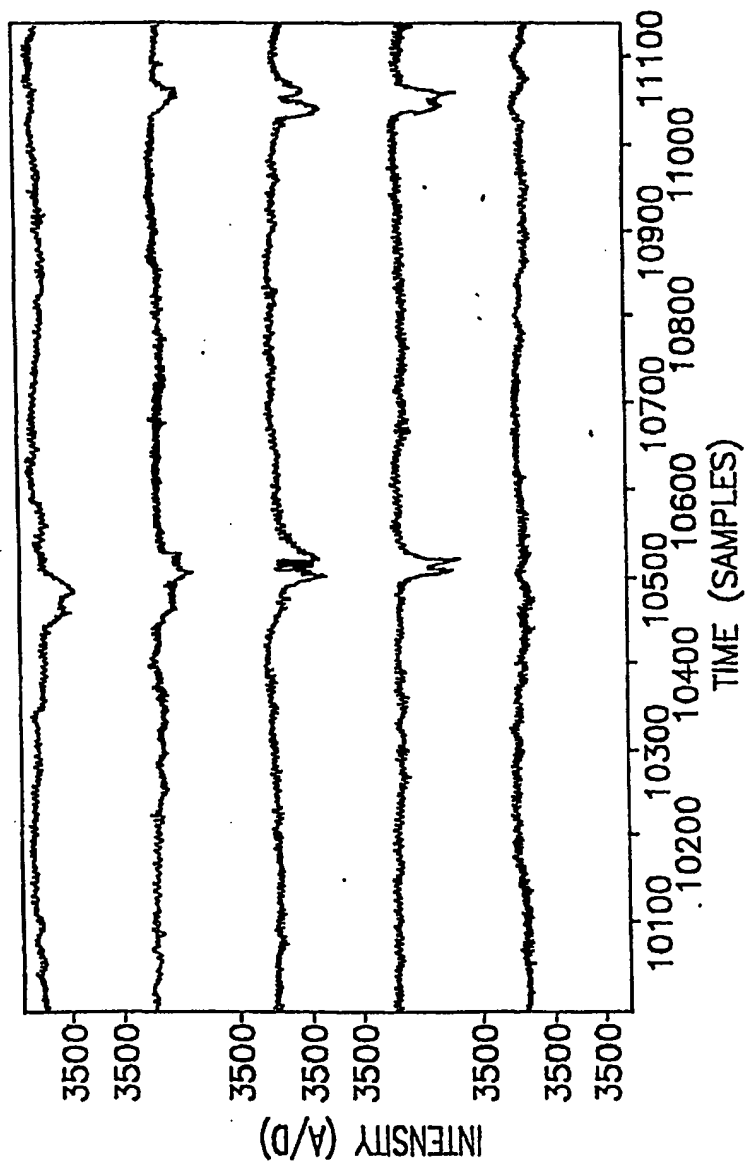


FIG. 29B

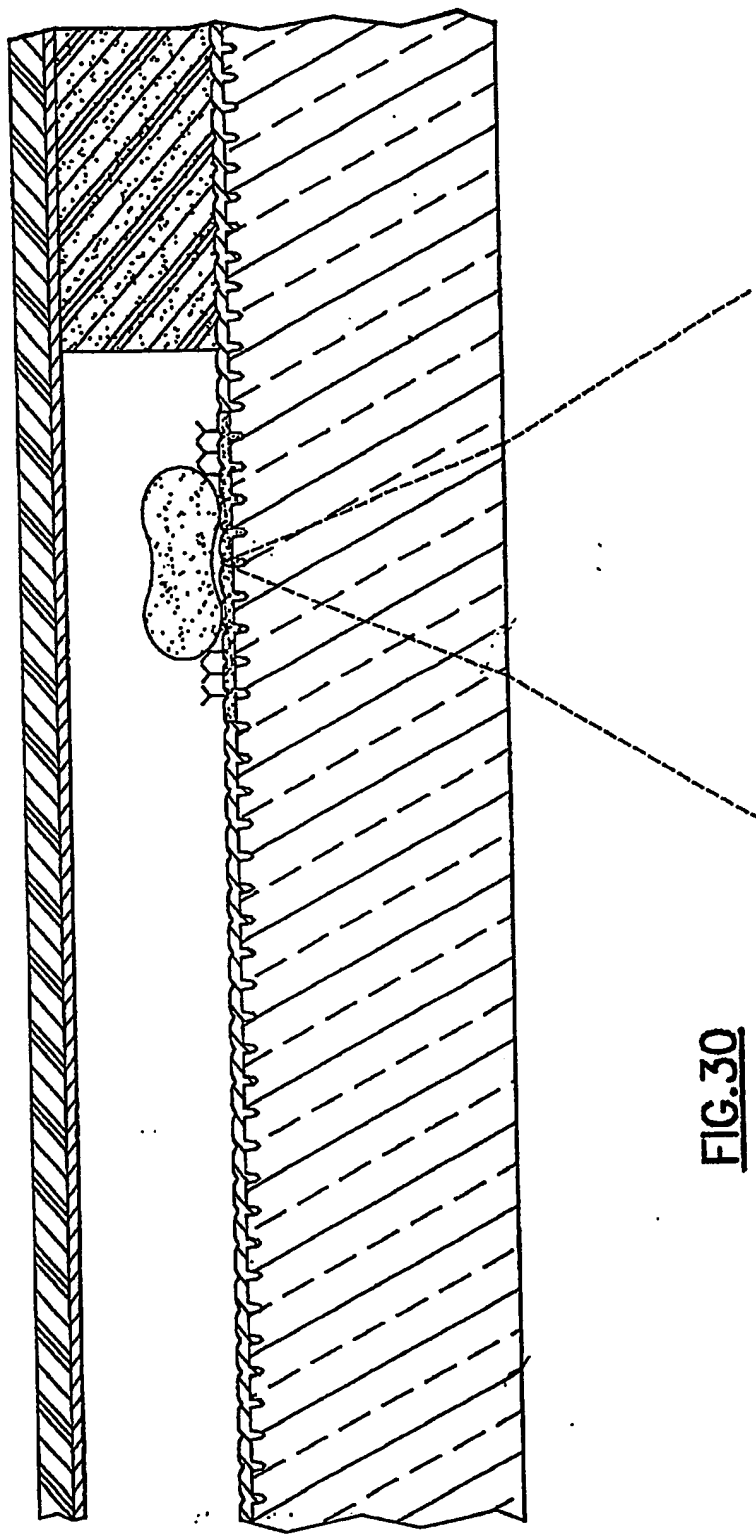


FIG.30

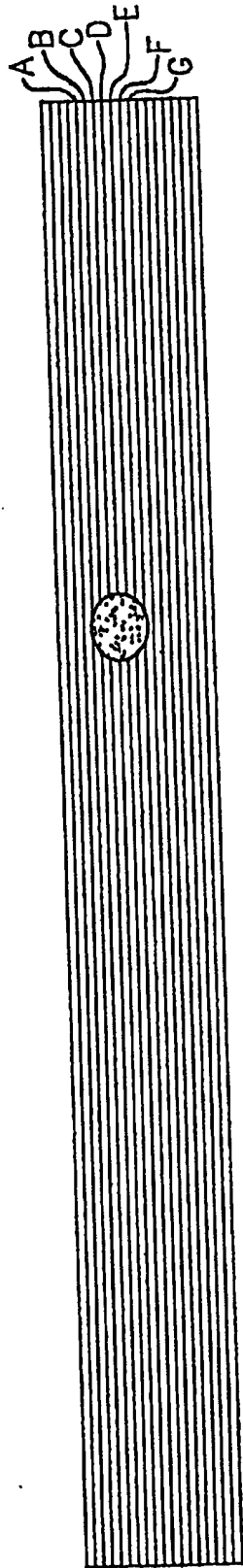


FIG.31A

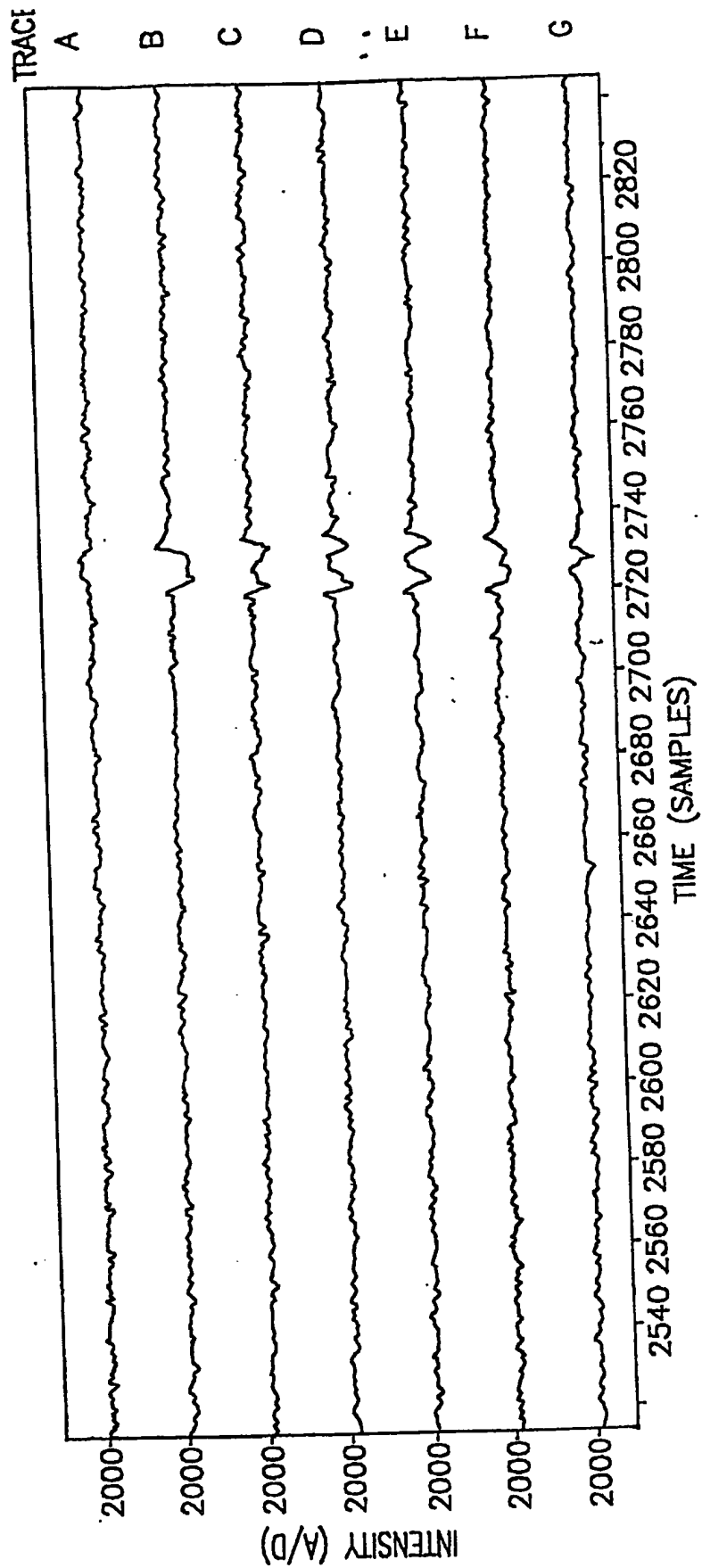


FIG.31B

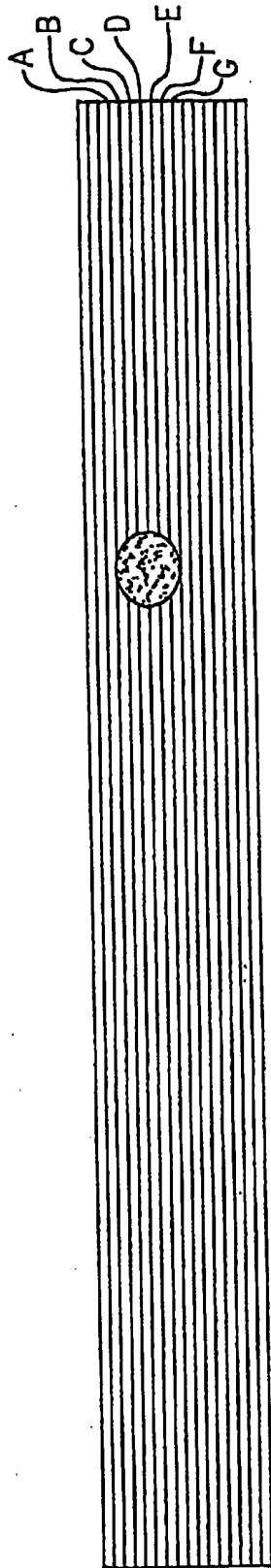


FIG.32A

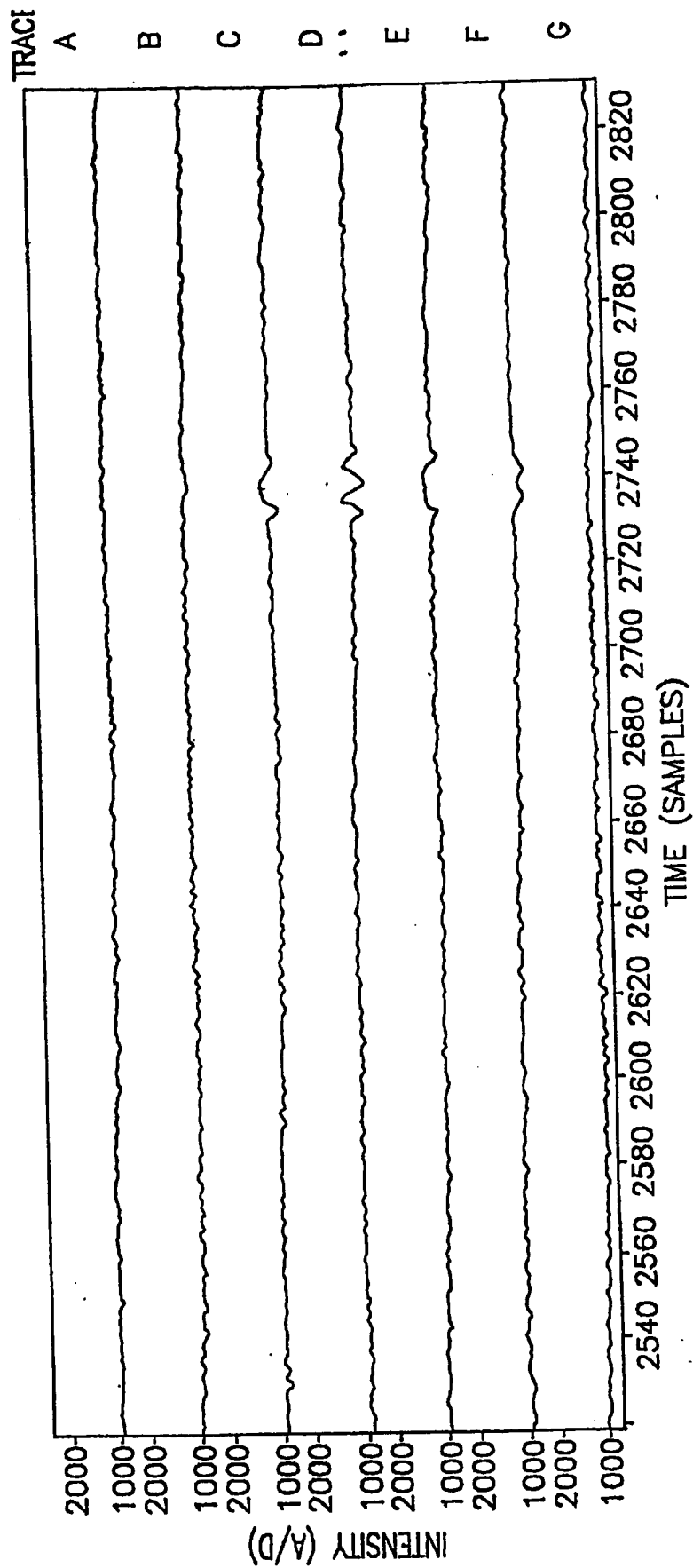


FIG.32B

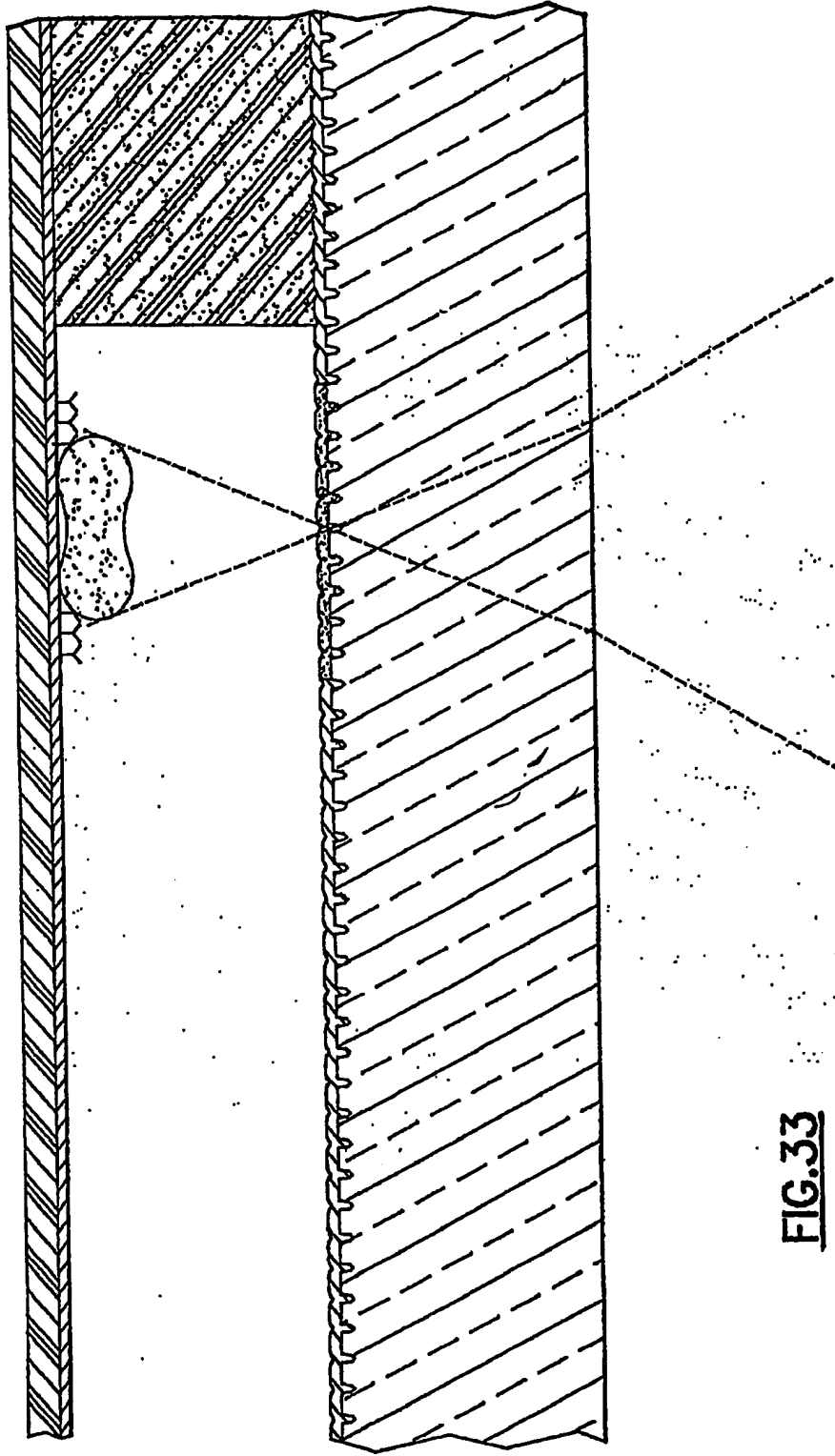


FIG.33

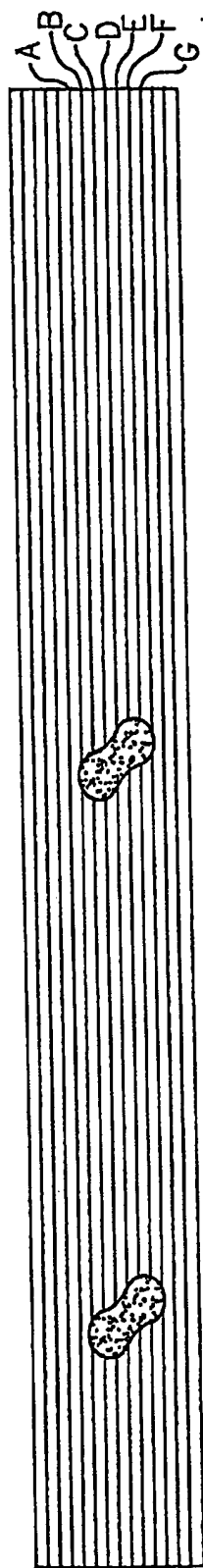


FIG. 34A

TRACE

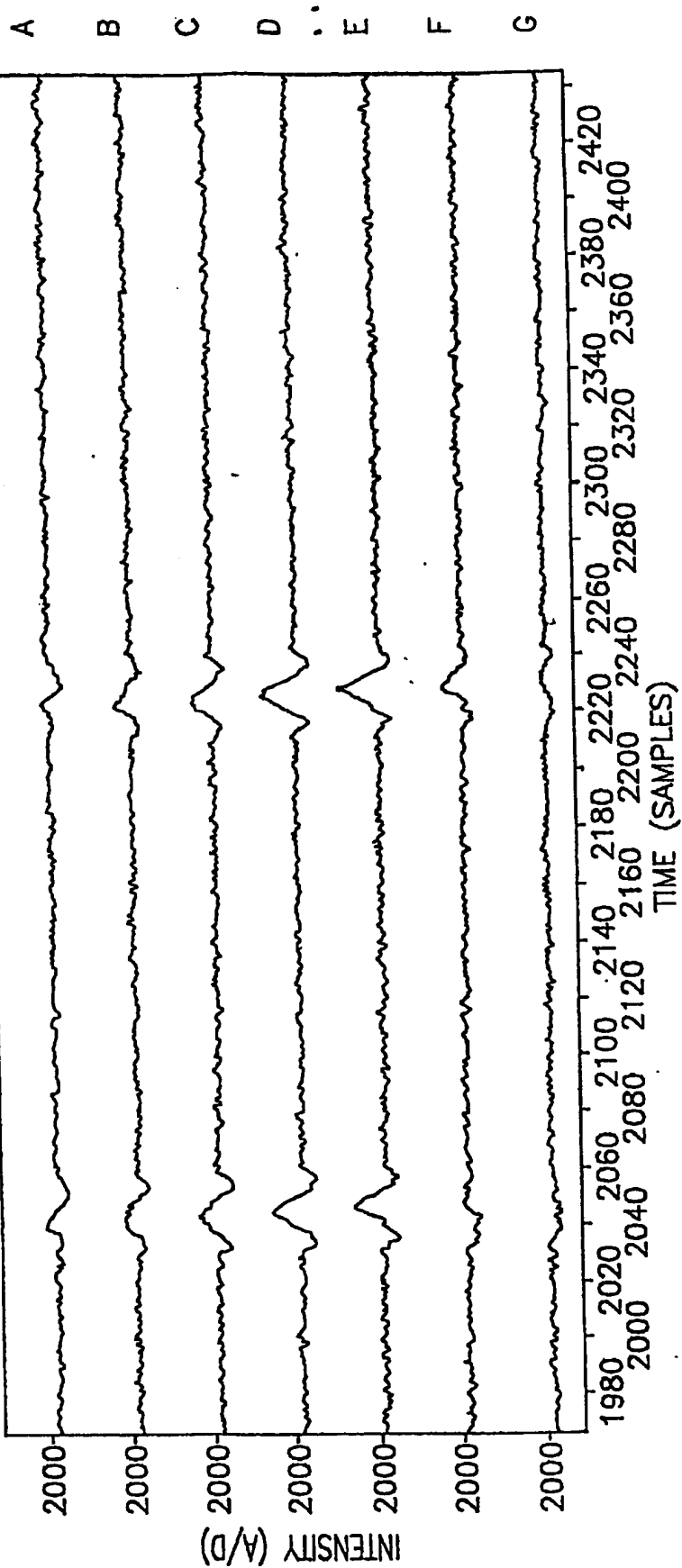


FIG. 34B

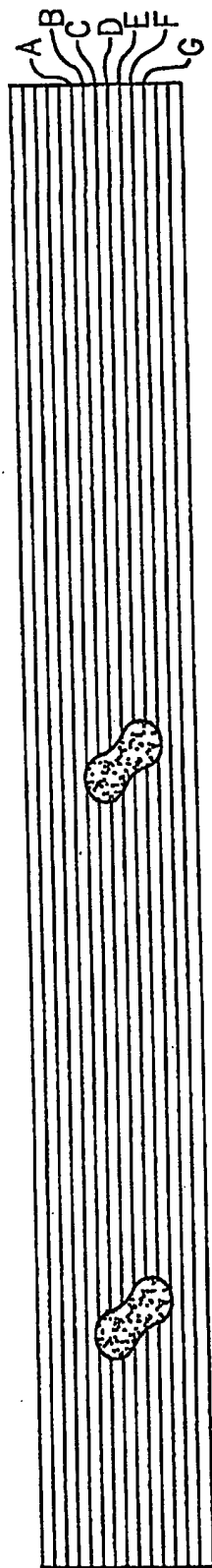


FIG. 35A

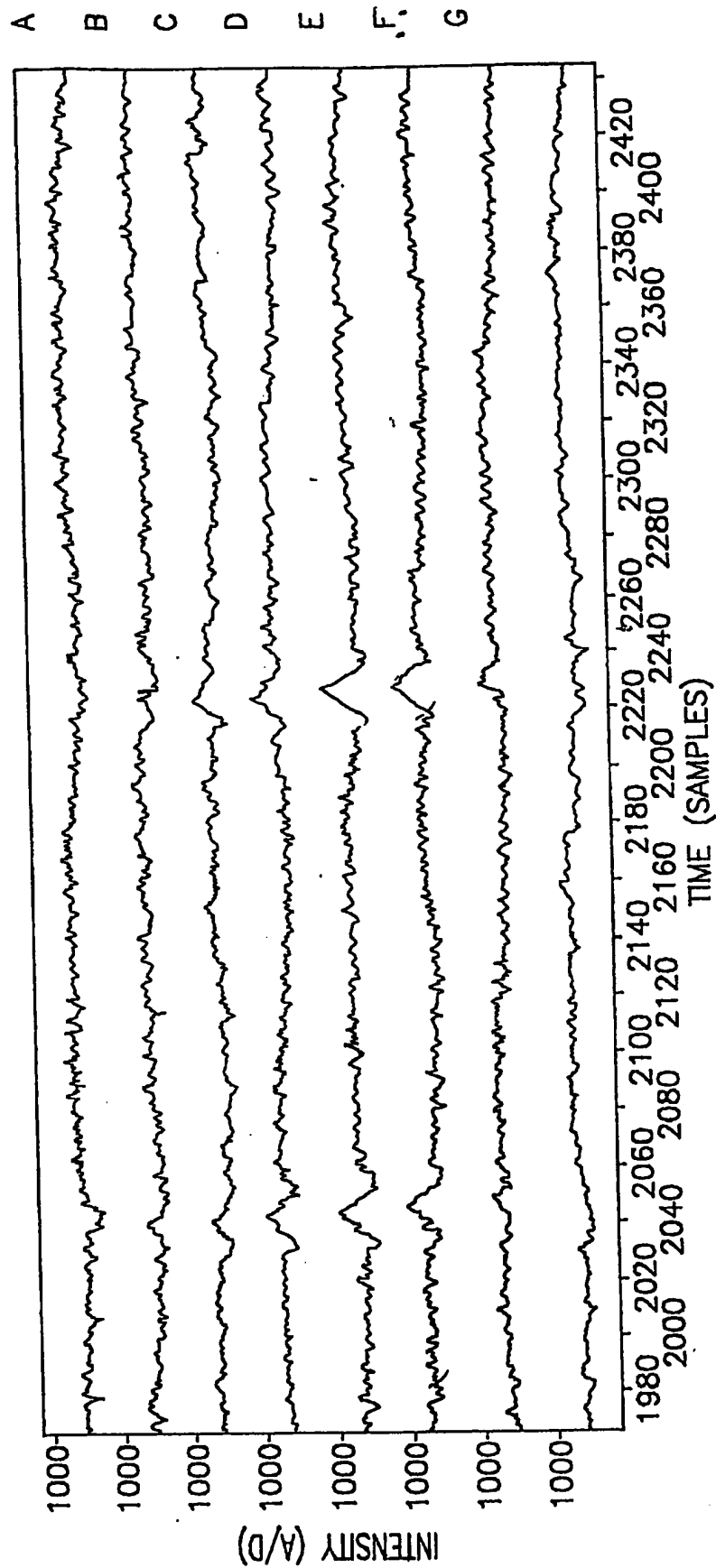


FIG. 35B

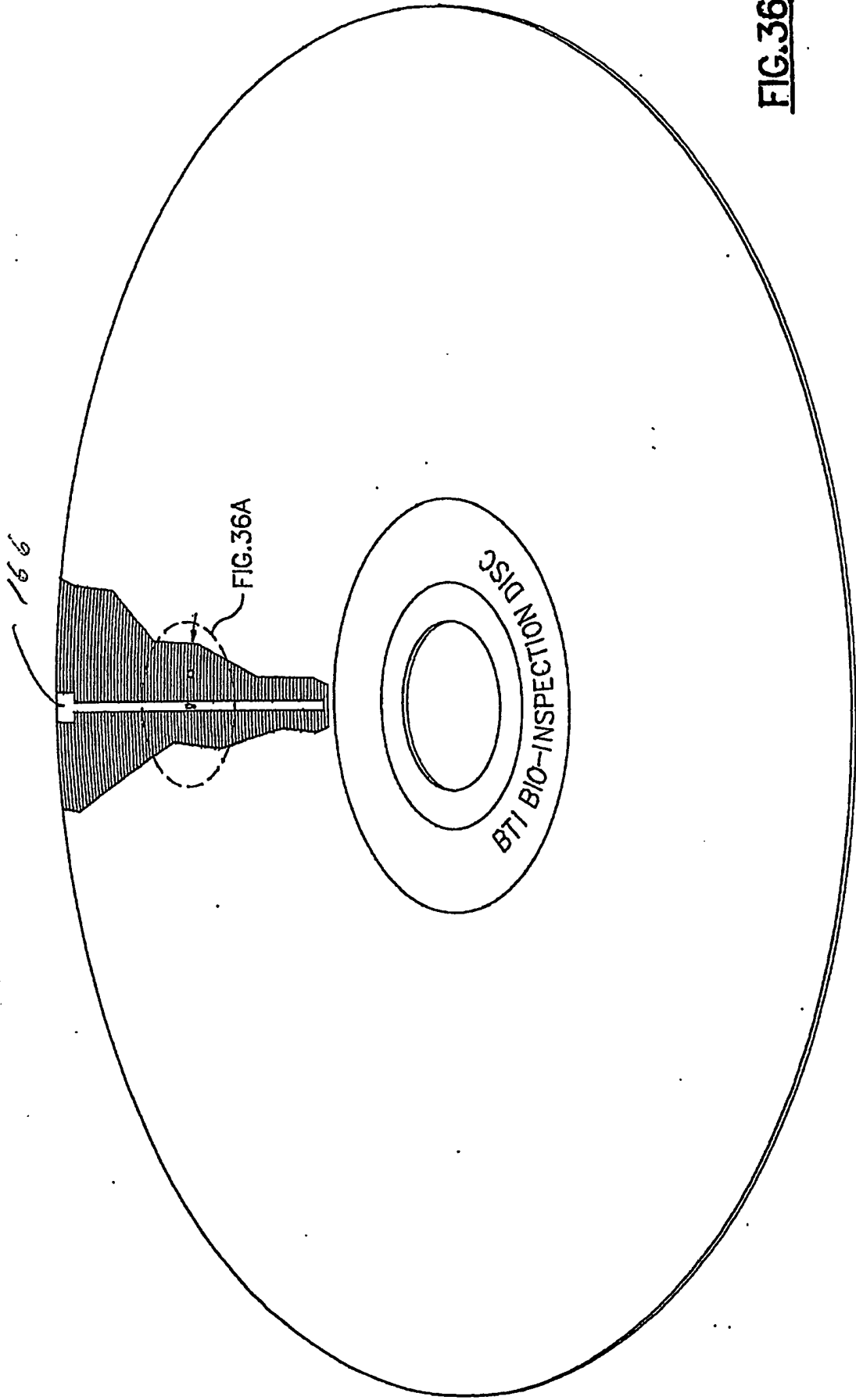


FIG. 36

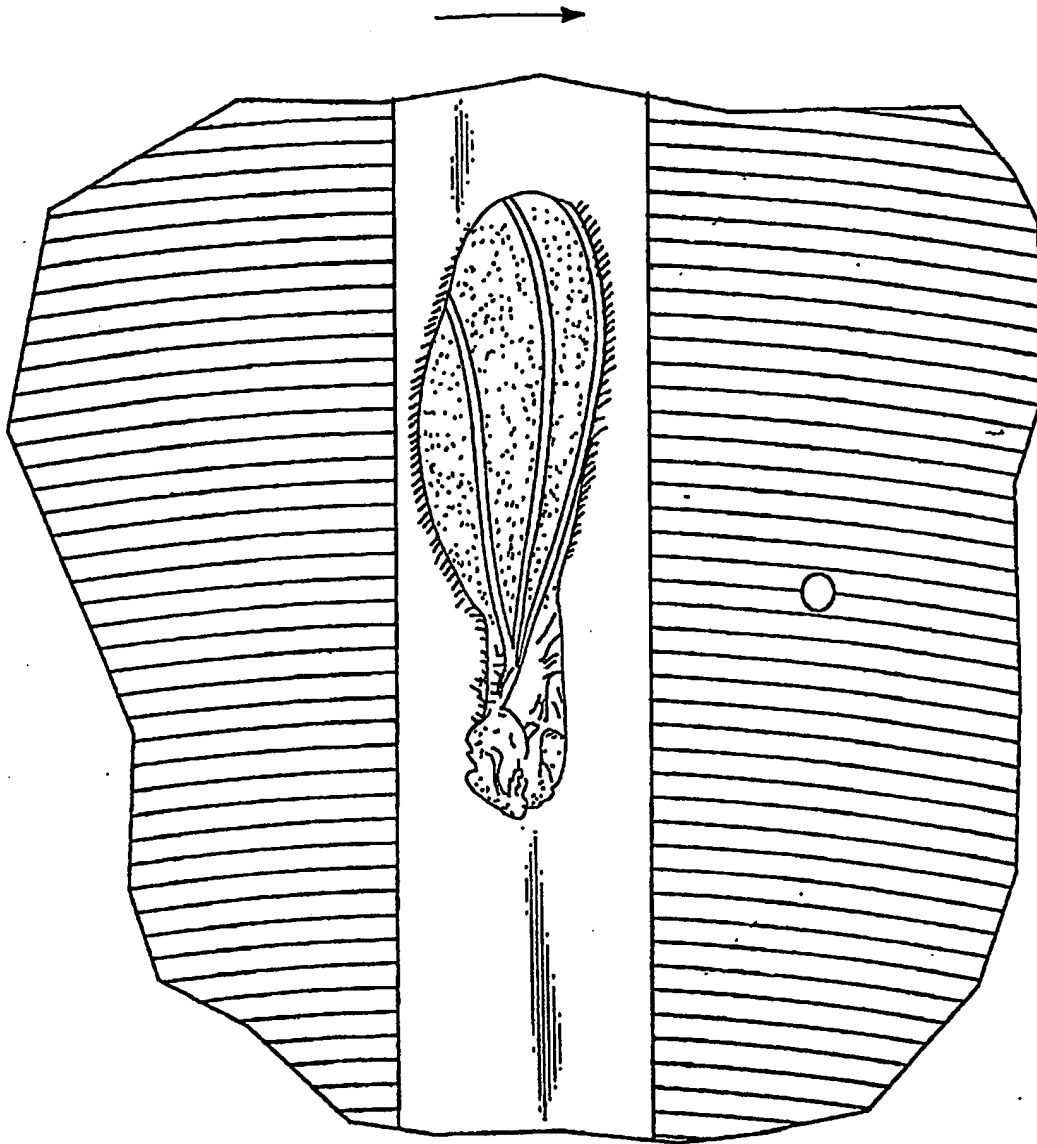


FIG.36A

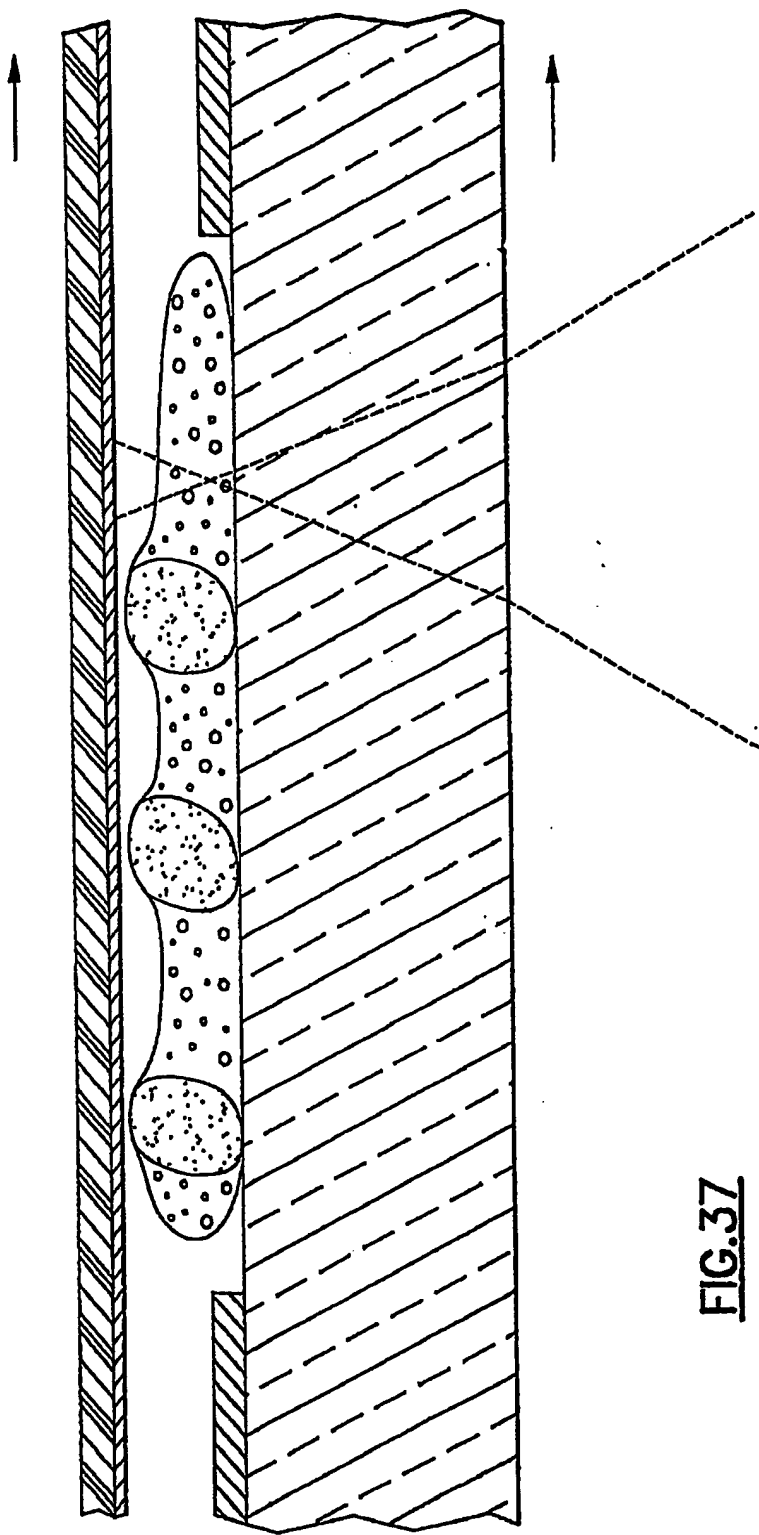


FIG. 37

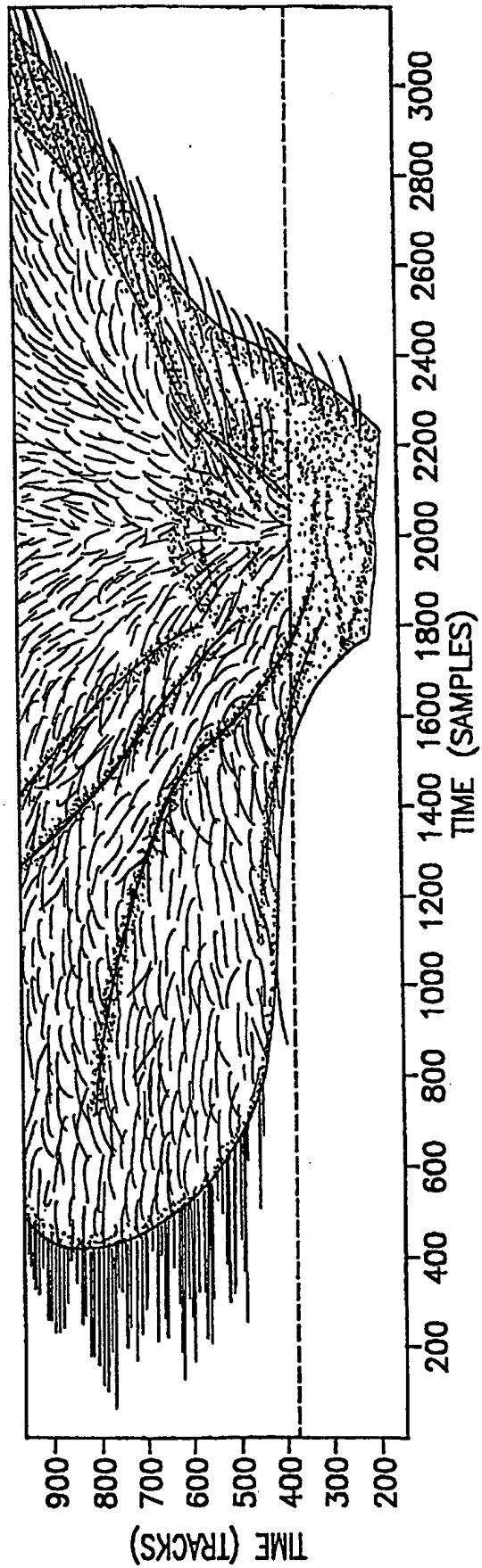


FIG. 38A

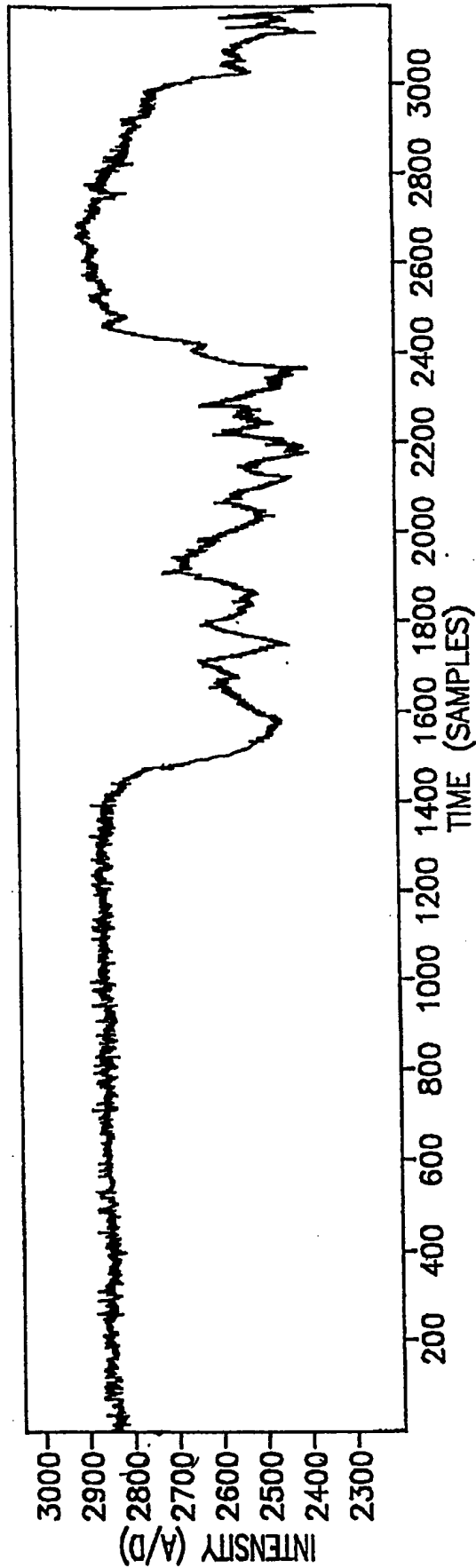


FIG. 38B

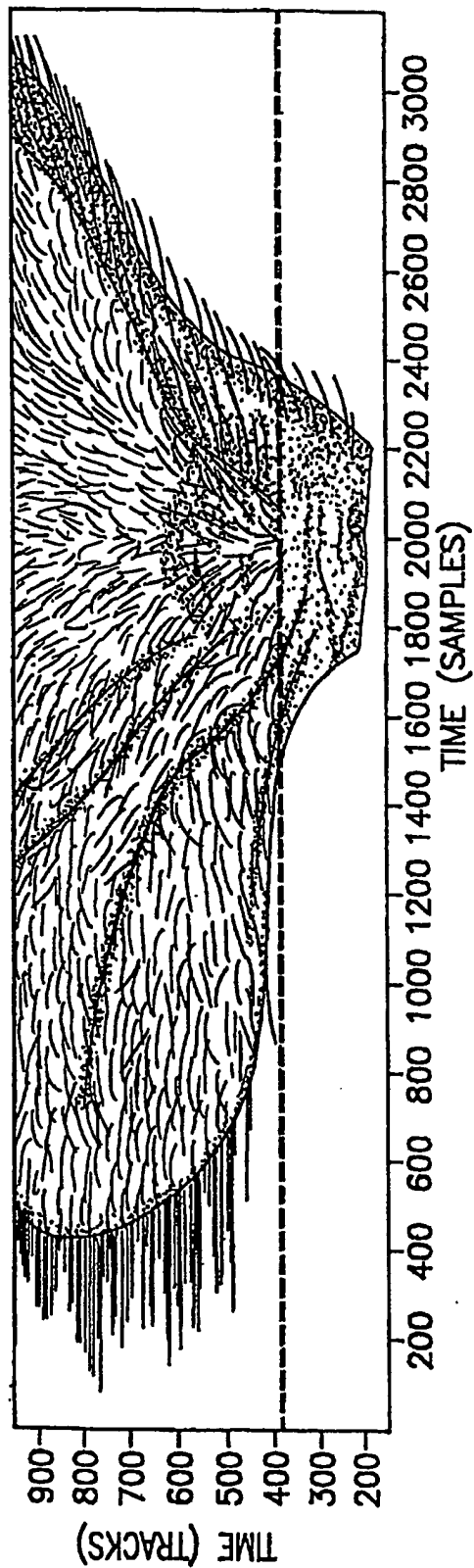


FIG. 39A

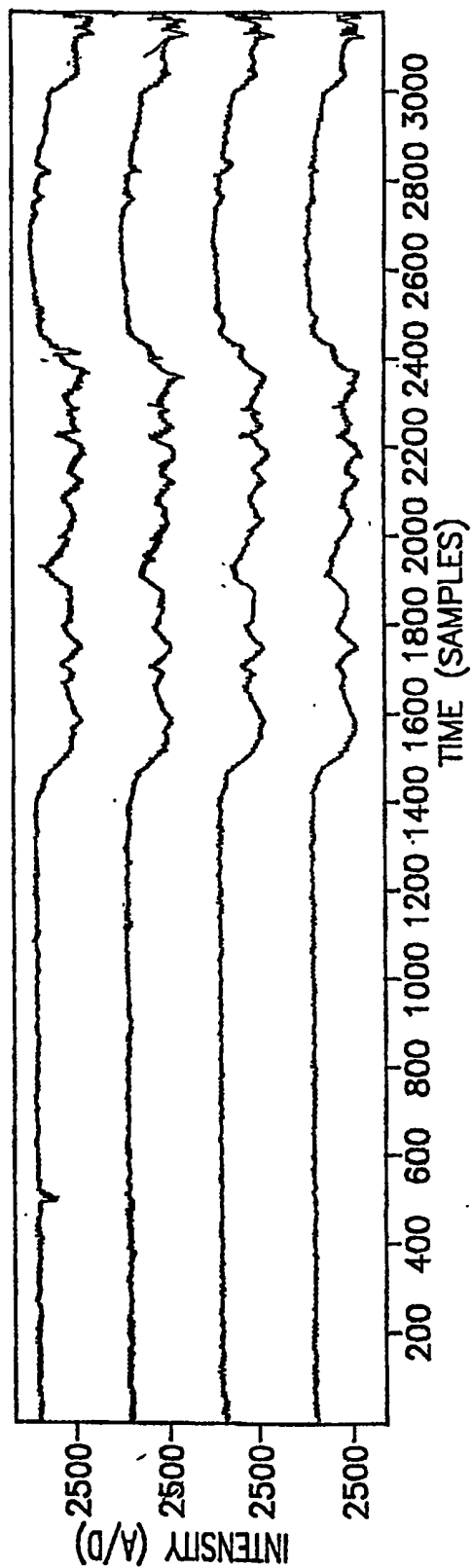


FIG. 39B

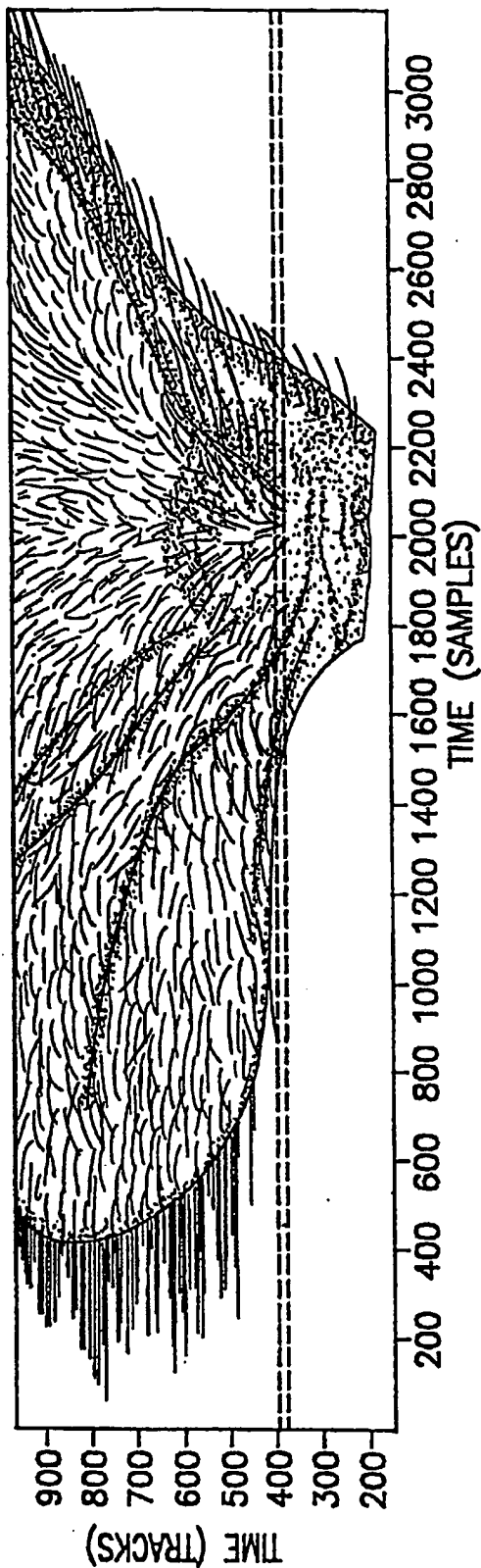


FIG. 40A

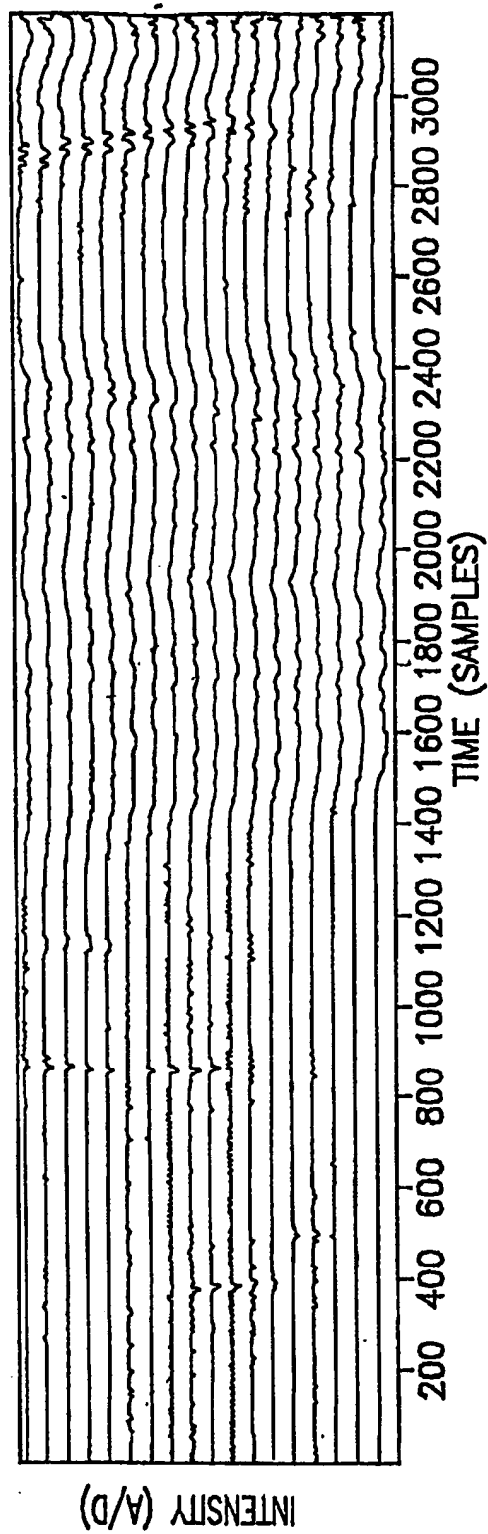
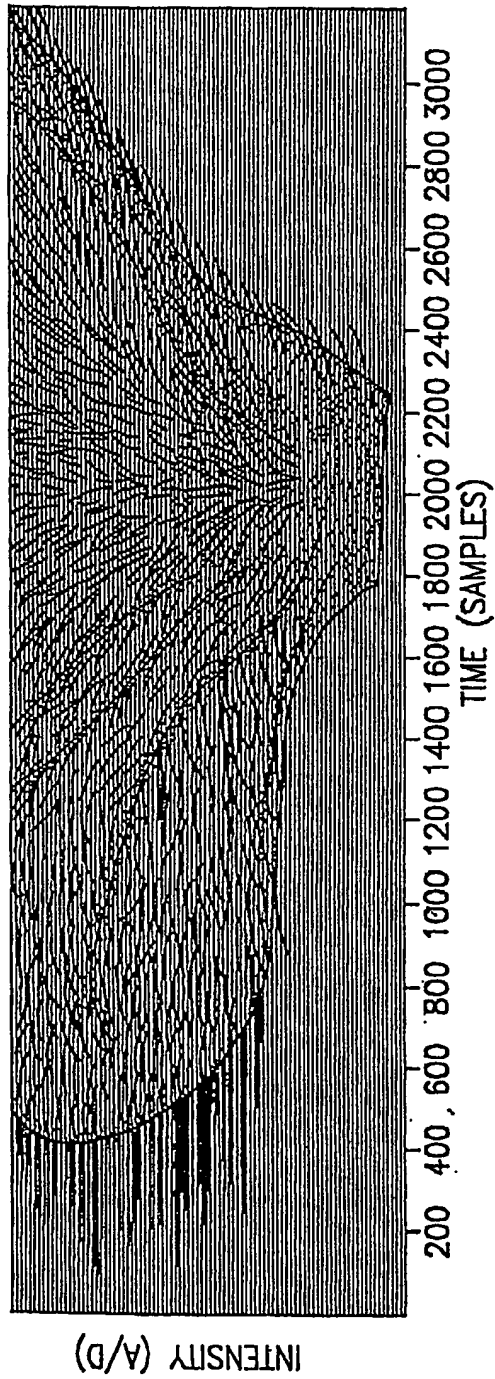
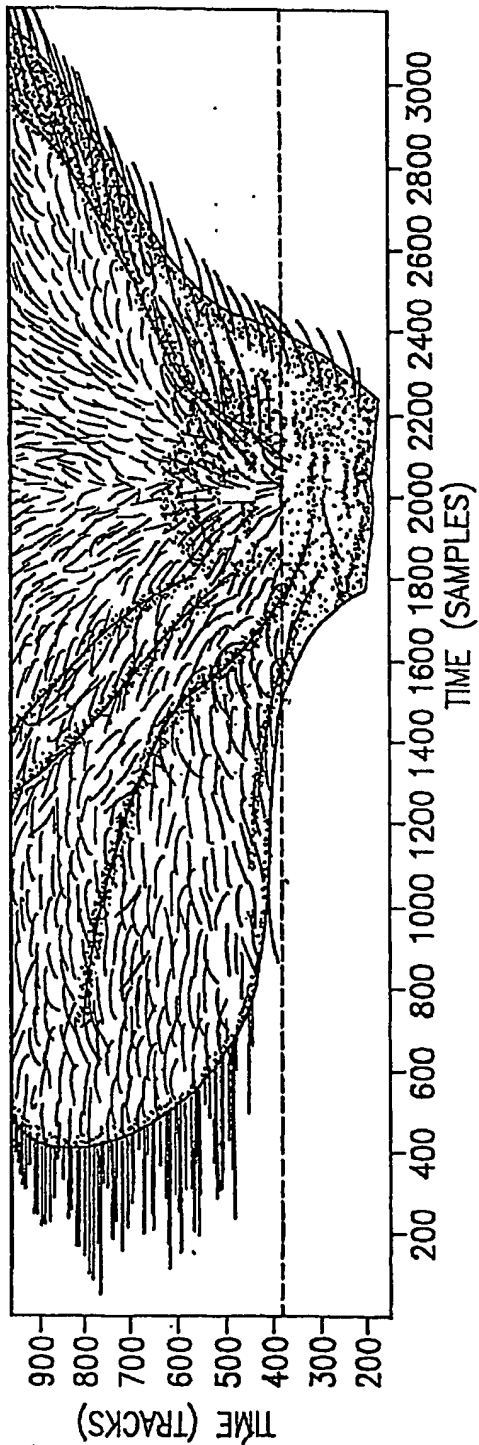


FIG. 40B



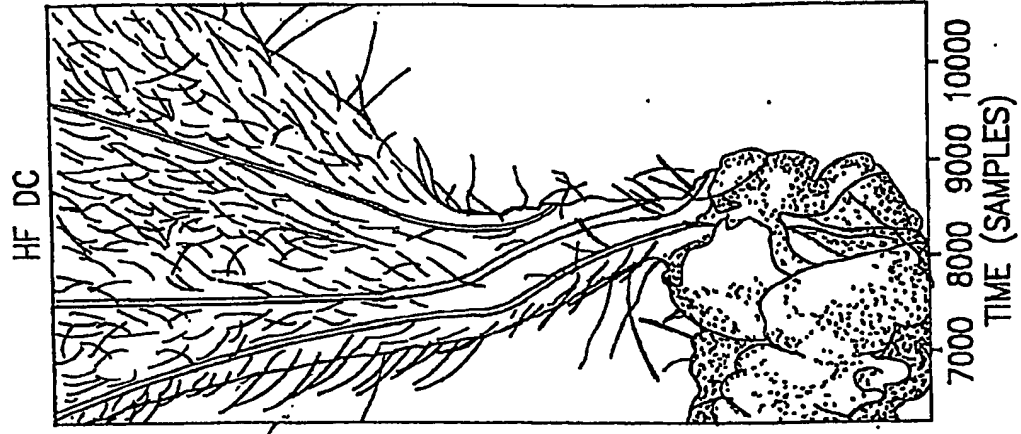


FIG. 42A

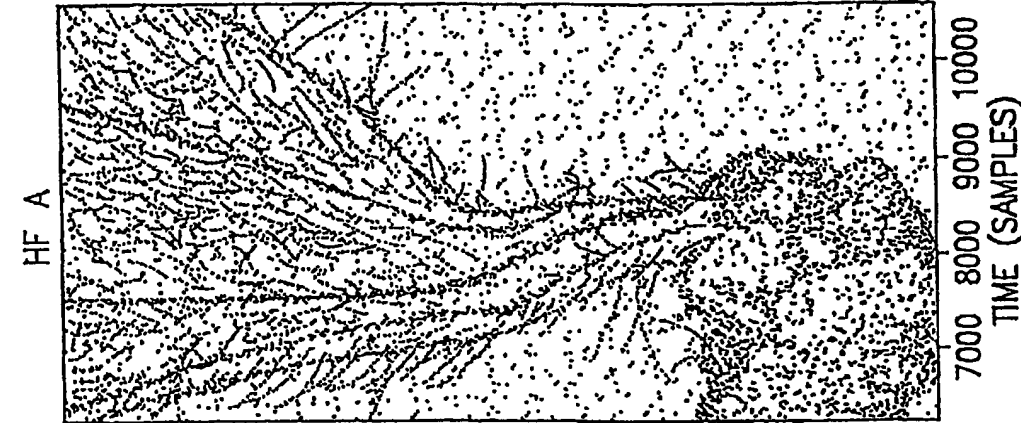


FIG. 42B

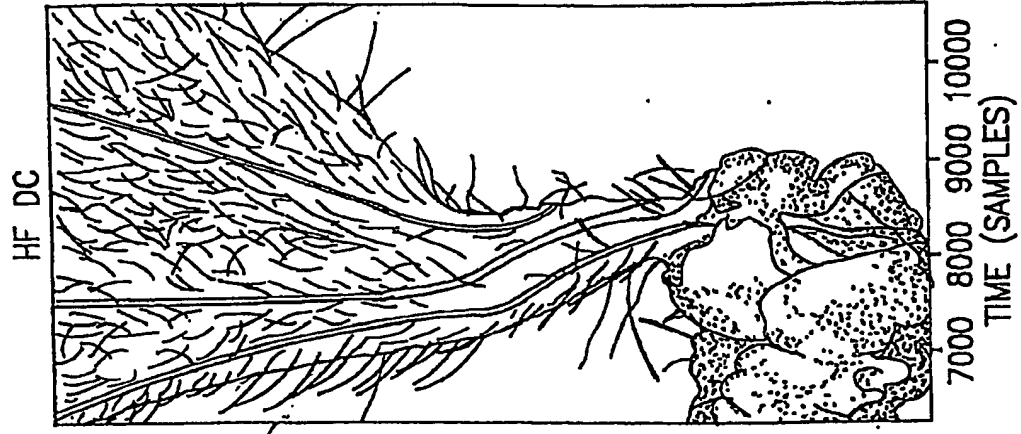
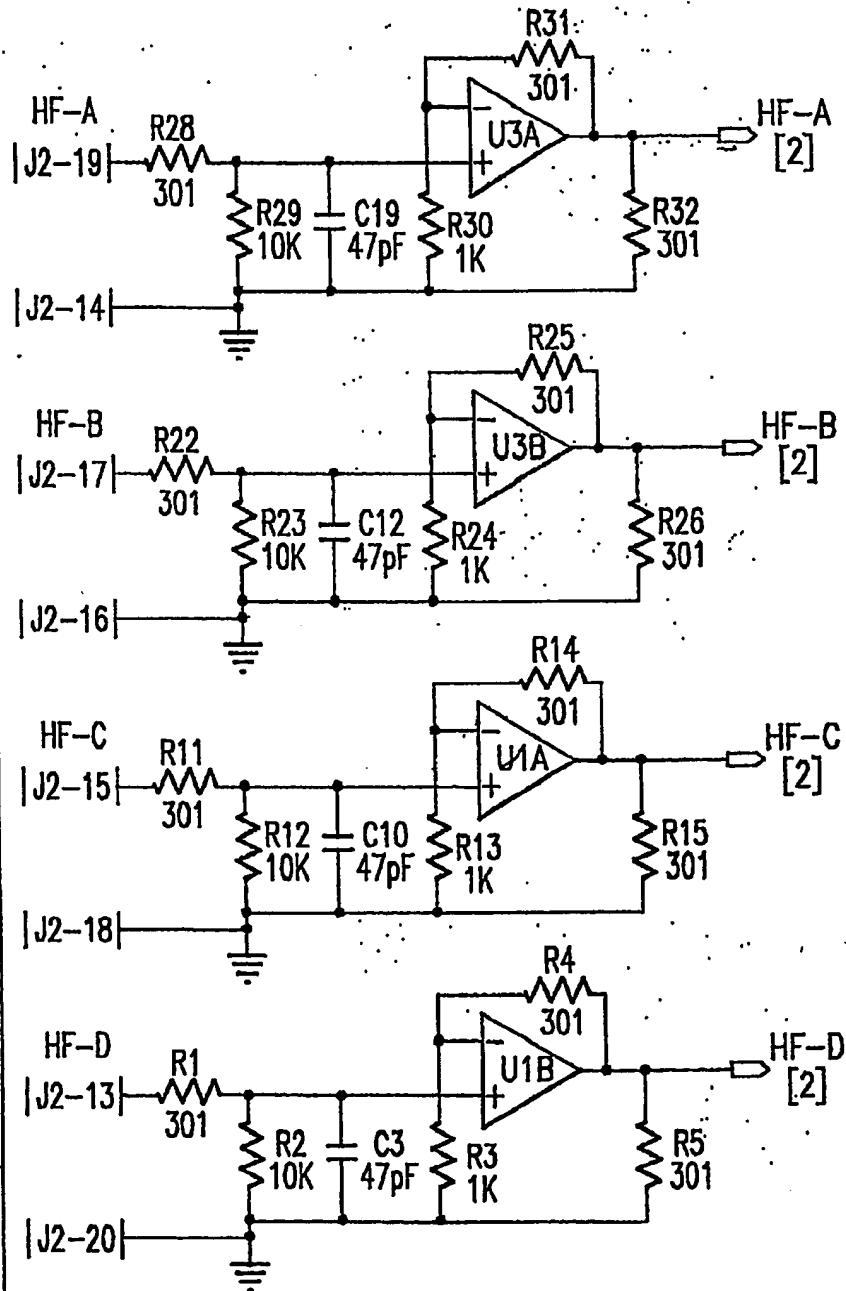


FIG. 42C

FIG.43A	FIG.43B
	FIG.43C

FIG.43

FIG.43A



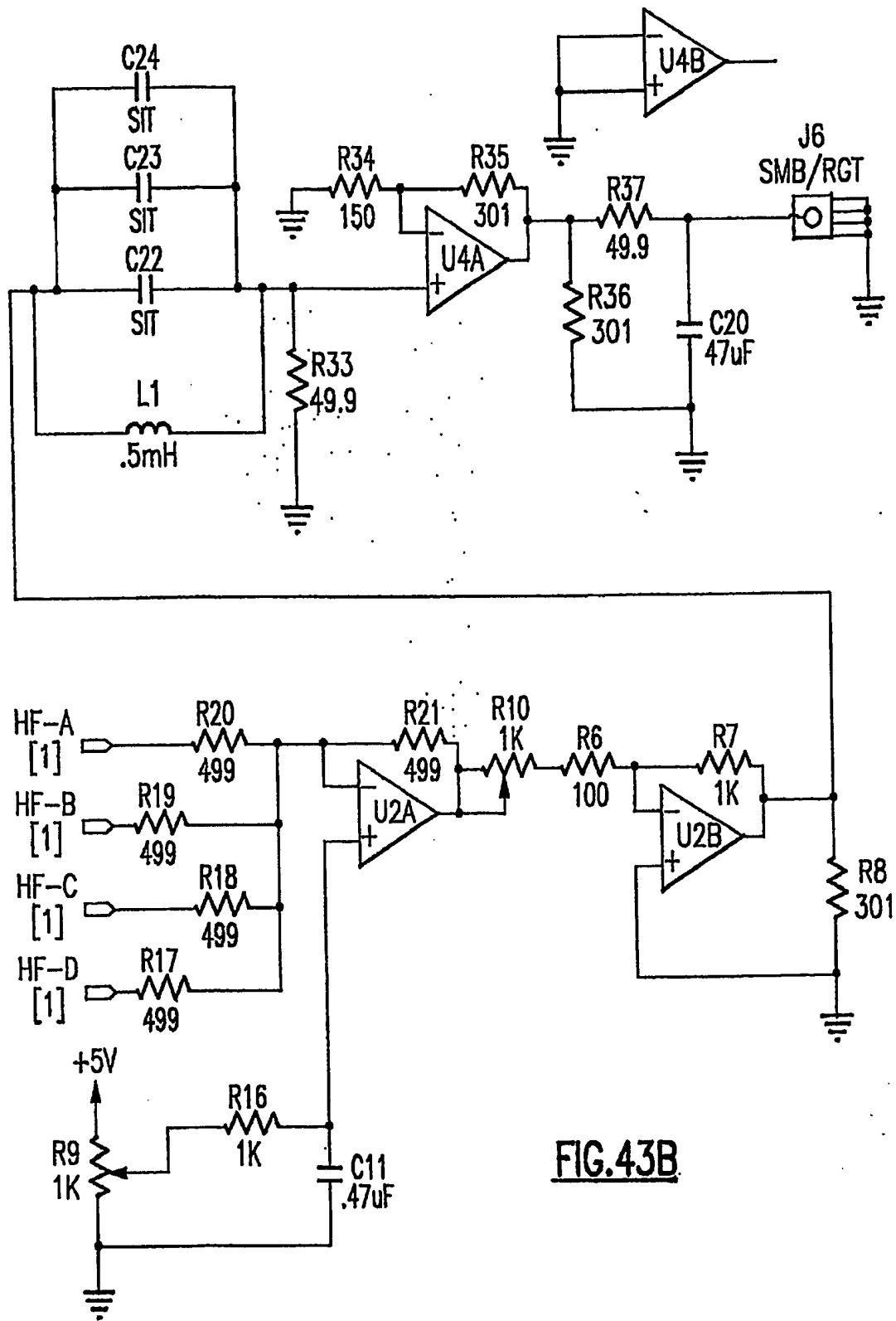


FIG.43B

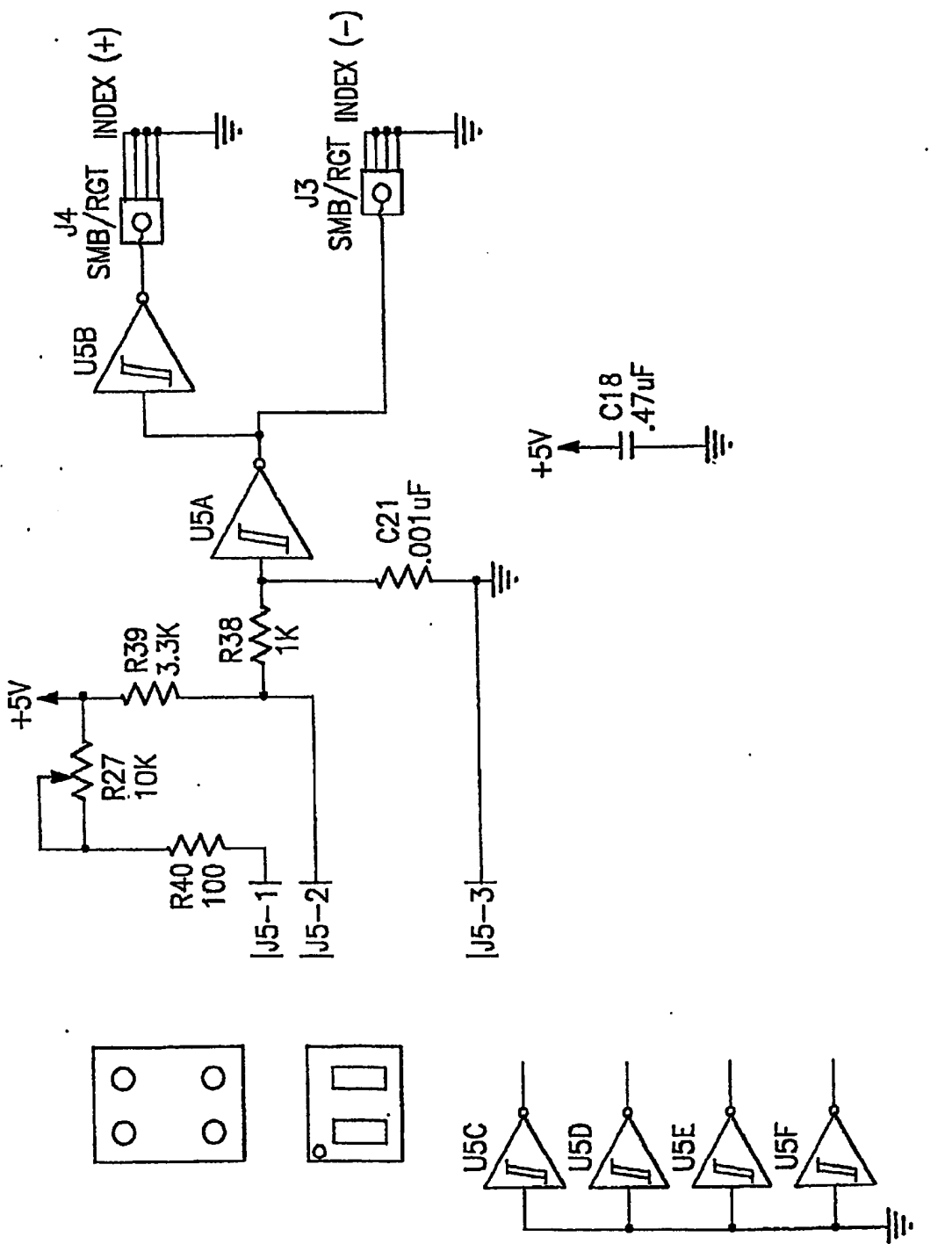


FIG.43C

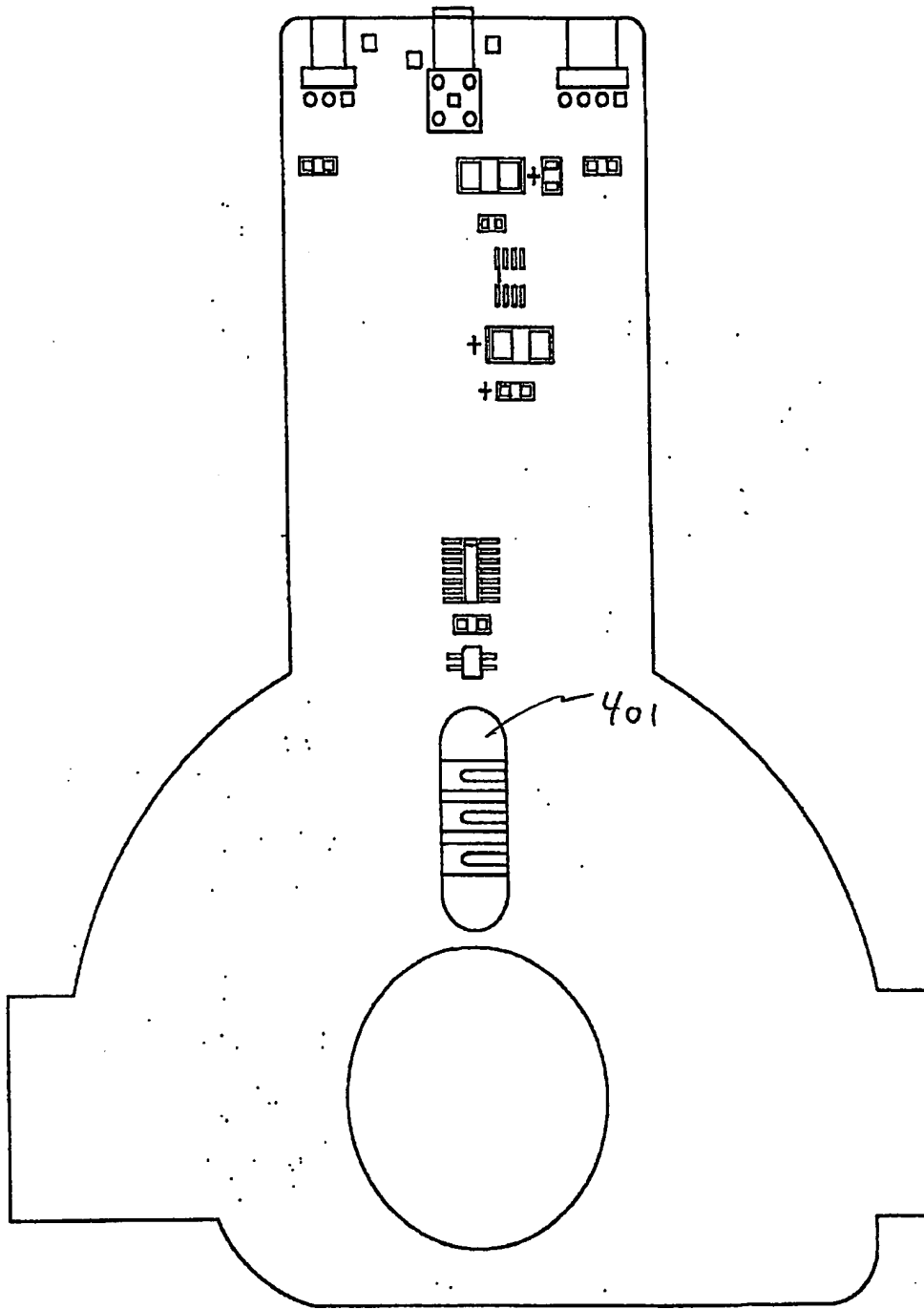


FIG.44

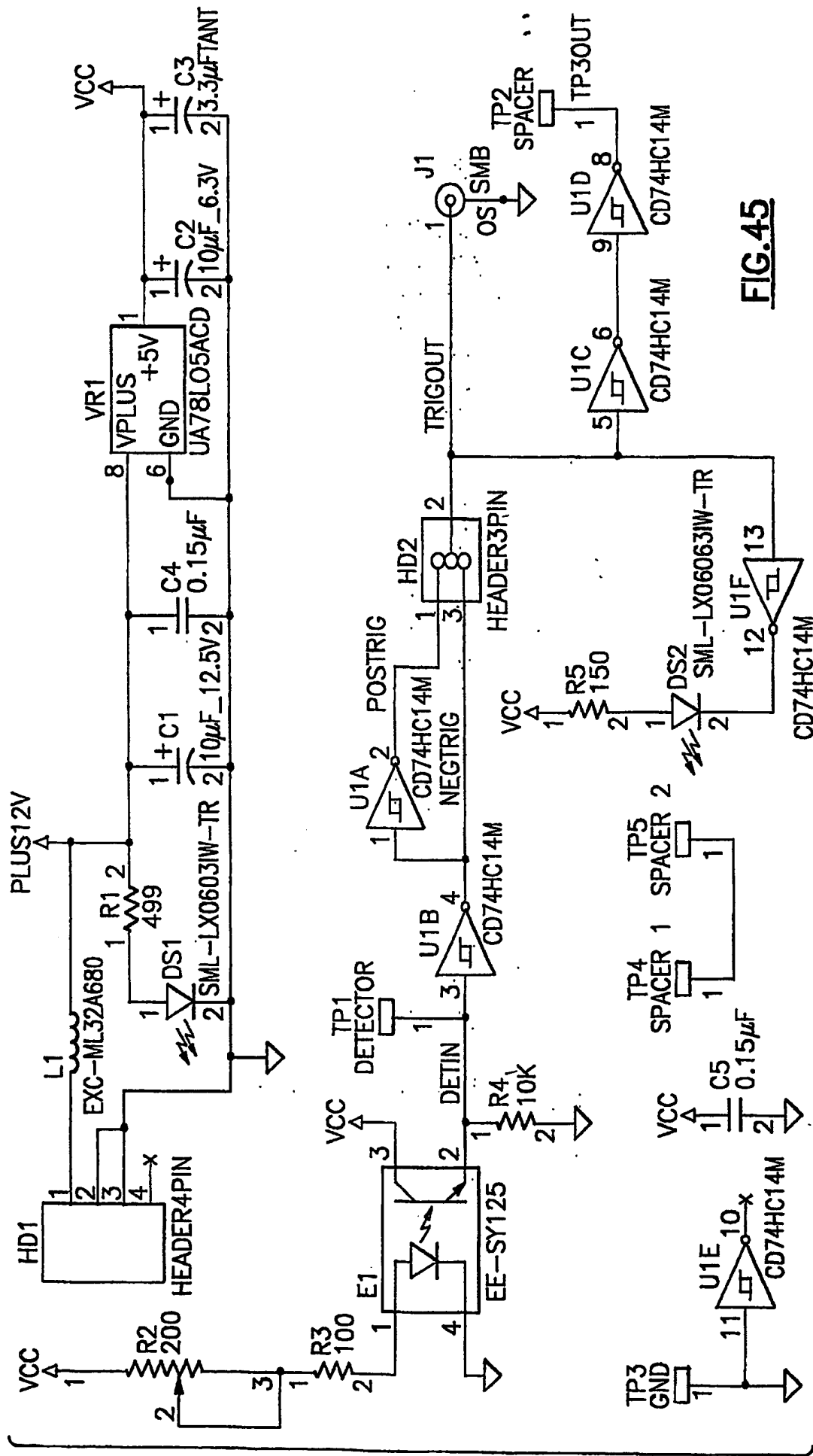


FIG.45

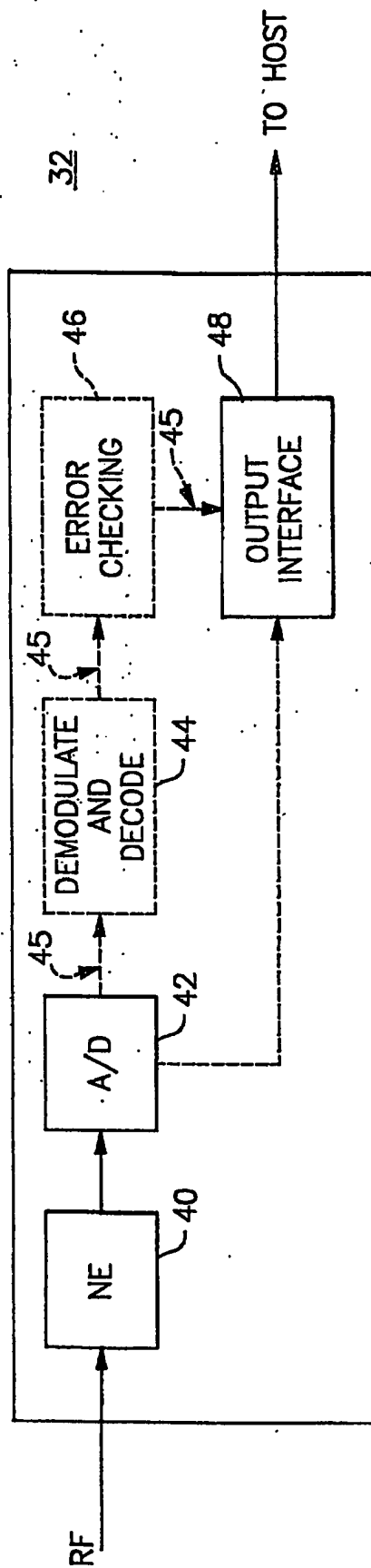


FIG. 46

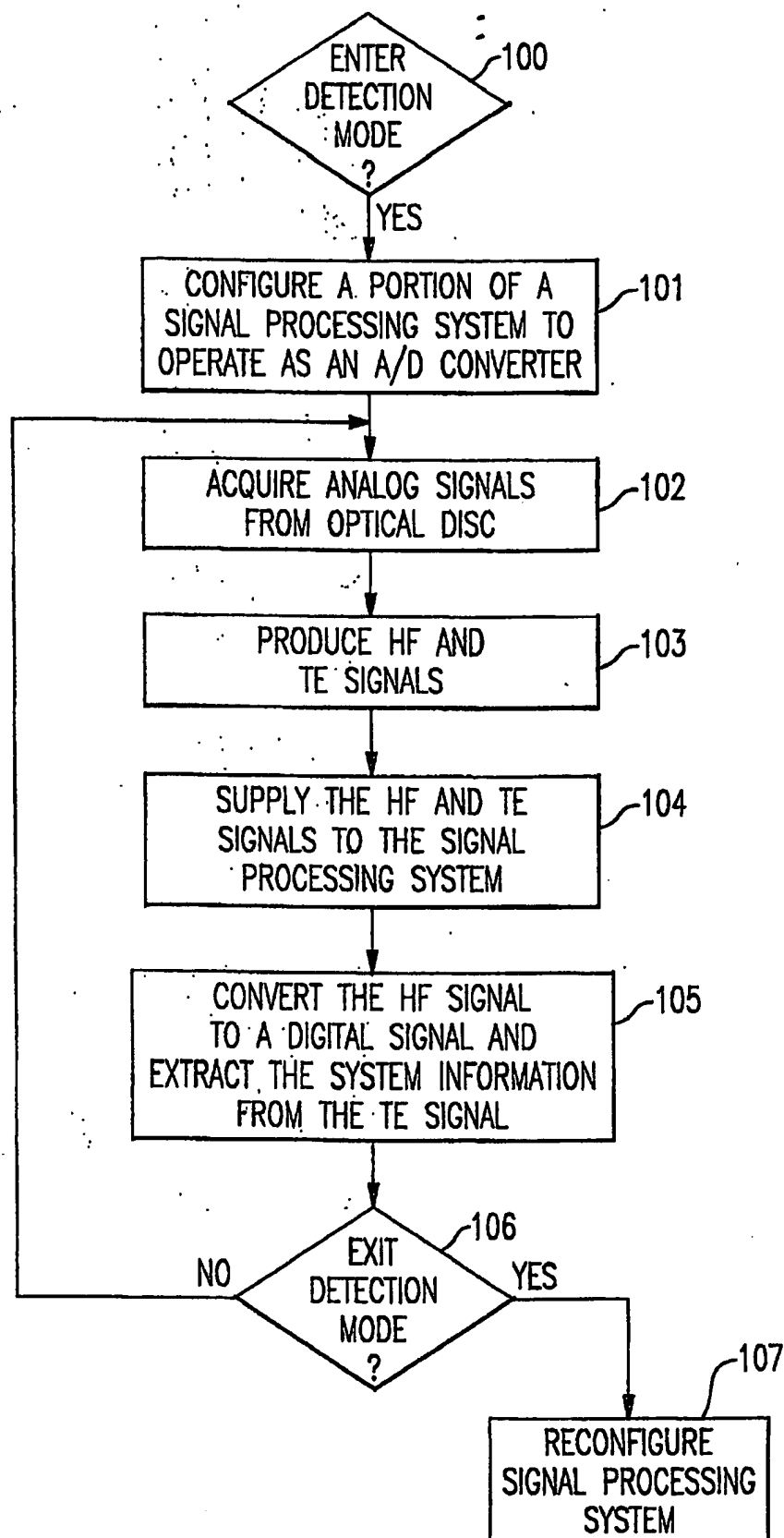


FIG.47